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How to Use Equipment Specifications to Predict Measurement Uncertainty

James L. Taylor
Aerospace Testing Alliance

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APPROVAL STATEMENT

Prepared by:

James Taylor

JAMES L TAYLOR
Aerospace Testing Alliance

Reviewed by:

Simon Choi

SIMON CHOI
Test Project Manager
TTSI

Terry Harris

TERRY HARRIS
Project Manager
Aerospace Testing Alliance

Approved by:

John J Walters

JOHN J. WALTERS
Deputy Director
Propulsion Wind Tunnel Ground Test Complex

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Taylor, James L.
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14. ABSTRACT
This report illustrates a methodology for predicting data system measurement uncertainty using equipment specifications. The example presented is based on the data acquisition systems being built for Tunnels ABC. For this example, the measurement uncertainty is predicted for both voltage and force balance measurements. The analysis identified several error sources that could potentially prevent the system from meeting the requirements. Mitigation measures were identified that would enable the proposed system to meet the requirements.

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1.0 INTRODUCTION

1.1 BACKGROUND

AEDC's test units use general purpose steady-state data acquisition systems to measure and acquire different phenomenon from the test articles being tested. This includes pressure, temperature, and force. A standard requirement is that the quality of the measured results must be quantified and provided to those who use the results. This enables others to compare the results (Ref. 1). AEDC uses the concept of measurement uncertainty to provide a quantifiable indication of the quality of measured results. For wind tunnel applications, the AIAA Standard S-071A-1999 (Ref 1) is used. For turbine engine applications, the ASME PTC 19.2-2005 (Ref 2) is used.

Historically, the measurement uncertainty for data acquisition systems has been experimentally determined after the system was installed and operational. An experiment is conducted wherein known inputs are applied at the system's input and the outputs recorded. Error sources such as the effects of temperature, time drift, and calibration interval are estimated and combined with experimentally determined errors to establish measurement uncertainty.

Over the years, experimental evaluation of uncertainty has largely gone by the wayside as a result of shrinking budgets. In its place, the system designer's estimate of measurement performance has been used. This estimate is based on interpretation of manufacturers' specifications and an understanding of the application. For this type evaluation, the individual parameter specifications or attributes (also referred to as errors) are combined using the Root Sum Square (RSS) method (Ref. 3). Predicting measurement uncertainty using manufacturers' specifications is considered a conservative approach with a major benefit of aiding in identifying error sources that can be mitigated through calibration or operational procedures. When funding is available, the predicted measurement uncertainty should be replaced or augmented with experimentally determined measurement uncertainty.

1.2 PURPOSE

The purpose of this document is to provide a current example that demonstrates how to predict a data system's measurement performance using manufacturers' specifications and, in so doing, point out mitigation techniques for some errors. The example is the new data acquisition system being built for AEDC's small wind tunnels — Tunnels A, B, and C.

2.0 STATEMENT OF THE PROBLEM AND METHOD OF ANALYSIS

2.1 PROBLEM STATEMENT

The problem in using equipment specifications to determine measurement uncertainty has two parts. First, interpreting the different manufacturers' performance specifications is difficult because there are no industry standards that provide manufacturer guidance in what attributes or parameters to include as part of their product's specifications. For example, two different manufacturers of comparable products can have entirely different specifications. Second, combining the different attributes into an estimate of measurement uncertainty is complicated because there are no standards that provide manufacturer guidance in how to quantify the different attributes. Manufacturers' specifications are subject to varying interpretations, leading to differences in the methods used to interpret specifications. This inconsistency could lead to a potentially flawed interpretation and an incorrect estimate of measurement uncertainty (Ref. 4).

The result could be that the system, when built and tested, fails to meet the requirements. Even so, the manufacturers' specifications represent the best estimator of performance, but they must be used with caution.

2.2 BACKGROUND

The new system will replace aged equipment and will be used as a general purpose data system. The system will be custom configured for each specific test. Since the system will be used to measure low-frequency or steady-state phenomena, the design emphasis is on performance, specifically measurement uncertainty. Bandwidth and sampling rate are requirements but are not included in this discussion. Also, sensor excitation in the form of either constant voltage or constant current is required for some of the different measurement types. Finally, all critical measurements at AEDC must be traceable to national standards. Since a large, multichannel system such as this must be calibrated in place as opposed to periodically transporting the system to a calibration laboratory for calibration, the system must include a National Institute of Science and Technology (NIST) traceable calibration standard that is used to calibrate the system in place and provide the required traceability.

It has been previously determined that the system will be designed as a multiplexed data system in which multiple inputs share a single analog-to-digital converter (ADC). To compensate for both noise and common mode voltage, each analog input will be configured using a differential amplifier for each channel and will include appropriate filtering to accommodate the different measurements. The multiplexer/ADC can be configured as a single-ended device since it is in close proximity to the amplifier outputs.

2.3 MEASUREMENT PERFORMANCE REQUIREMENTS

The measurement performance requirements for the critical force balance and voltage measurement types are listed below in Table 1. The requirement is that the uncertainty in the measured value will be less than the stated requirement to a probability of 95%. This is denoted as $U_{95.}$.

Since the Tunnel ABC system will be a general purpose data acquisition system capable of acquiring data from various input devices, the standard practice is to establish the data acquisition system's measurement uncertainty independent of the input source. This allows the total measurement uncertainty for any specific measurement to be developed by combining the data system's measurement uncertainty with the measurement uncertainty of the input sensor or transducer. For example, to establish the total uncertainty for a measurement such as a load cell or force balance, the uncertainty of the data acquisition system would be combined with the uncertainty of the load cell or force balance using the RSS technique.

The measurement errors for both the general purpose voltage measurements and the force balance measurements are assumed to be normally distributed. This assumption is reflected in Table 1 below where the requirement for measurement uncertainty is stated in terms of 95% coverage or ±2σ (Ref. 3). Since the system will be designed to accommodate a wide range of full scale input voltages, the accepted practice is to state uncertainty in terms of a percent as % FS. If FS is used, it must be defined such as FS = 10 mV or FS = x psia, etc. Since this is a replacement system, the threshold requirement in Table 1 represents the existing capability and is the minimum acceptable performance. In contrast, the objective requirement represents the desired performance assuming there is no impact on cost.

Table 1. Partial List of Tunnel A, B, C Measurement Requirements

Measurement	Threshold U_{95}	Objective U_{95}
General Purpose Voltage	±0.04%FS	±0.02%FS
Force Balance	±0.05%FS	±0.02%FS

2.4 APPROACH

The approach to establishing an estimate of measurement uncertainty is to identify equipment to meet each requirement. For example, the force balance requirement is ±0.05% FS on the 10-mV range. As a minimum, this will require a power supply to provide excitation to the force balance strain gauge, an amplifier to condition the low-level analog signal, and an analog-to-digital converter to convert the analog signal to digital format. The existing process used in other AEDC wind tunnels is to constantly measure the excitation voltage being applied to the force balance and to correct for any variations in the excitation. As a result, two separate data system channels are used for each force balance channel — one to measure the balance voltage and one to measure the applied excitation voltage or current. This is the approach used for the new data system force balance channels as well. All of the equipment (the two amplifiers, the excitation power supply, and the multiplexer/ADC) have elemental errors identified in the manufacturer's specifications that contribute to the total measurement uncertainty.

To illustrate, the performance specifications for an instrumentation amplifier can include accuracy, zero, nonlinearity, noise, drift, common mode rejection, input bias current, and the effect of temperature on both gain and offset. All are considered independent of each other. To estimate overall or total performance, these various performance specifications or errors must be statistically combined. In addition, the effects of temperature on both gain and offset are specified as a temperature coefficient and can be quantified for a specific application by using an allowance for the change in temperature. The methodology for combining elemental errors is to convert each specification into a standard uncertainty (Ref. 5). This requires that both the frequency distribution and confidence interval be known so that each specification can be adjusted to achieve a standard uncertainty. If the frequency distribution is not known, a reasonable default approach is to use a rectangular or equal probability distribution (Ref. 3).

The various standard uncertainties are combined using the RSS method to establish the combined standard measurement uncertainty (Ref. 3). When using manufacturers' specifications, it is assumed that they are all independent. An additional assumption is that the measurement performance is modeled by a normal distribution. The expanded uncertainty or total uncertainty is determined by multiplying the standard uncertainty with a coverage factor such as 2 or 3 (Ref. 3). A coverage factor of 2 defines the interval that will contain 95%, and 3 would be used to define the 99.7% interval.

2.5 THE METHODOLOGY SUMMARIZED

The recommended design methodology consists of the following:

1. Sketching a block diagram of the system by identifying the various equipment that forms the system, identifying the signal voltages, and identifying the methodology that will be used to achieve traceability of the measurements to national standards

2. Using manufacturer specifications to identify all relevant performance attributes and list each under the appropriate system equipment

3. Identifying those equipment specifications which are affected by the environment and computing the effects of each based on an understanding of the operating environment. For measurement systems, temperature is the dominant environmental factor affecting both gain and offset.

4. Converting each specified parameter or system attribute into a standard uncertainty in consistent units such as % FS or volts

5. Combining the different standard uncertainties using the RSS technique. Note that all of the specifications must be in consistent units such as V or % FS before they are combined. Note that in some engineering applications, it is necessary to separate the elemental errors into systematic and random error categories and to combine these using RSS.

6. Applying a coverage factor of 2 to the combined standard uncertainty to establish $U_{95.}$

3.0 RESULTS

3.1 GENERAL PURPOSE VOLTAGE MEASUREMENTS

Figure 1 illustrates a simple functional block diagram of the proposed system for measuring analog parameters. As shown, the system includes an Agilent reference meter which is used to provide traceability to national standards. The system consists of an instrumentation amplifier per channel followed by a shared multiplexer/analog-digital-converter which is interfaced to a computer. To accommodate a wide range of measurements, the input amplifiers have differential inputs and operate from ±5mV to ±10V FS. The requirement as listed previously is ±0.04% FS, 95% Confidence, ±10mV FS.

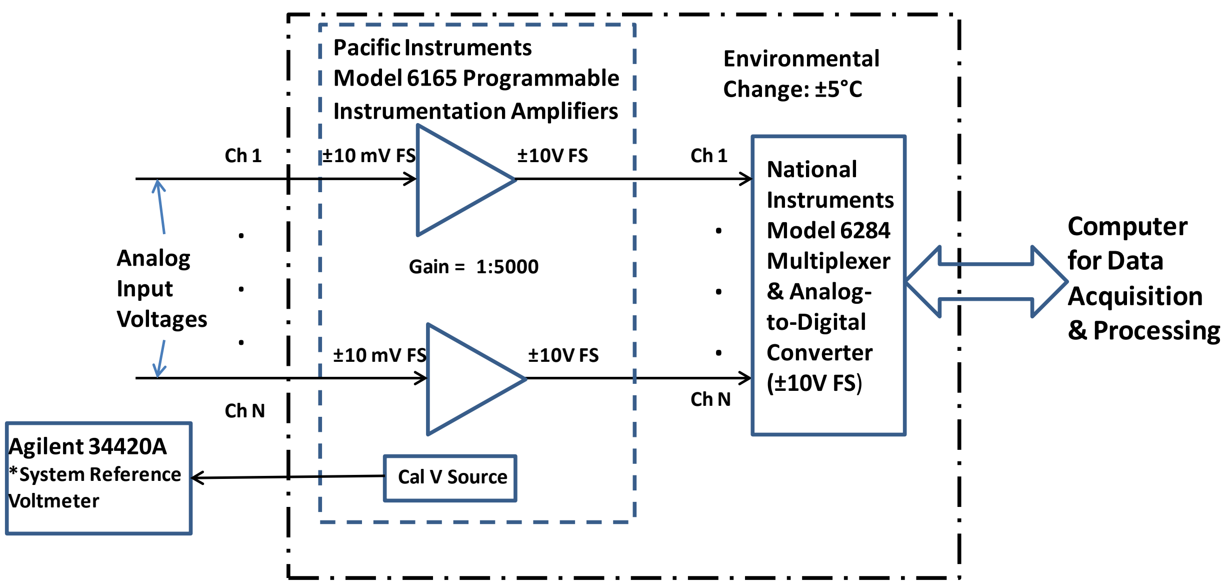

Figure 1. System Block Diagram

3.1.1 PACIFIC MODEL 6100/6165 PROGRAMMABLE INSTRUMENTATION AMPLIFIERS

The manufacturer's specifications listed below were confirmed with the manufacturer to represent 99.7% confidence and are assumed to be normally distributed. While not stated in the specification, specifications listed as % are assumed to be % FS. The specifications are included in the Appendix. Each specification is listed below and summarized in Table 2.

Gain Accuracy: There are 16 different fixed gain steps with an accuracy of ±0.05%FS. This represents a systematic error that can be reduced by computing the actual gain using a known voltage measured by the system reference voltmeter, Agilent 34420A.

Gain Stability, Time: ±0.02% FS for 30 days. Since the system is periodically calibrated in place, this error can be effectively mitigated.

Gain Stability, Temperature: ±0.005%/°C. Since the equipment can be exposed to a temperature variation of ±5°C, the thermal stability is the product of these two numbers or ±0.025% FS. This is a random error that is assumed to have a triangular distribution.

Linearity: ±0.01%FS for gains < 1,000 and ±0.02%FS for gains >1,000. Linearity is assumed to be a fixed error at any specific input and is normally distributed.

Common Mode Rejection Ratio: 60 dB plus gain in dB up to 120 dB for balanced input. Assuming a balanced input and using a gain of 1,000, the common mode is 120 dB. Assuming a common mode of ±5V, the common mode error is ±5 µV or ±0.00005% FS. For strain-gauge transducers where the common mode voltage is ½ the excitation voltage, this is a systematic error that can be effectively eliminated.

Zero: Automatic zero to ±2 µV RTI (relative to input) or ±1.0 mV RTO (relative to output). On a gain of 1,000, this is ±2.0 mV or ±0.02% FS and is a systematic error.

Zero Stability, Time: ±5 µV RTI, ±1.0 mV RTO. On a gain of 1,000, this is ±6 mV or ±0.06% FS. However, since the manufacturer's specification is for 1-year stability, this is not indicative of how the system will be operated. Typically, offset and span corrections are performed prior to testing. Accordingly, a 24-hr specification obtained from the manufacturer (±2 µVRTI ±0.4 mVRTO) applies. On a gain of 1,000, this error is ±2.4 mV or ±0.024% FS. This is a random error assumed to be normally distributed.

Zero Stability, Temperature: ±1 µV RTI, ±0.2 mV RTO/°C. On a gain of 1,000 and for a ±5°C change, this is 1.0 mV, ±1.0 mV or ±2 mV or ±0.02% FS. This is a random error with an assumed triangular distribution.

Source Current, Time: ±25 nA. Assuming a source impedance of 300 Ω, this produces an error at the amplifier output of ±0.075% FS. This is considered a systematic error.

Source Current, Temperature: ±0.05 nA/°C. Assuming a ±5°C change and a gain of 1,000, the error at the amplifier output is ±0.000025 V or ±0.00025% FS.

Noise (10 kHz): 2.0 µV RTI plus 0.3 mV RTO, RMS. On a gain of 1,000, this is 2.3 mV or 0.023% FS rms or 0.032% FS peak. This is a random error with an assumed triangular distribution.

In Table 2, the mitigated uncertainty represents the most probable estimate of uncertainty assuming the following:

1. Gain and zero uncertainties are mitigated to the uncertainty of the Agilent 34420A.

2. The system is routinely rezeroed during operations, so a 24-hr zero stability term is more appropriate.

3. The common mode voltage error for strain-gauge inputs is zeroed out as part of the operational procedures.

Table 2. Summary for Pacific Instruments Model 6100/6165

PARAMETER	SPECIFICATION, ±3σ	DISTRIBUTION	STANDARD UNCERTAINTY	MITIGATED UNCERTAINTY
Gain Accuracy, G = 1,000	±0.05% FS	Normal	±0.017% FS	±0.0018% FS, FS = 10 mV. Using Agilent 34420A
Gain Stability, Time	±0.02% FS	Normal	±0.007% FS	0.0%FS. The fixed error is removed as part of operational checks
Gain Stability, 5°C Temperature	±0.025% FS	Triangular	±0.01% FS	
Linearity, G = 1,000	±0.02% FS	Normal	±0.007% FS	
Common Mode (5V)	120 dB	Normal	±0.00002% FS	±0.0% FS. The fixed error is zeroed out for bridge inputs
Zero	±0.02% FS	Normal	±0.007% FS	±0.0018% FS. Using Agilent 34420A
Zero Stability	±0.024% FS	Normal	±0.06% FS	±0.008% FS. Using a 24-hr spec
Zero Stability, 5°C Temperature	±0.02% FS	Triangular	±0.008% FS	
Source Current-300 Ω, Time	±25 nA	Normal	±0.025% FS	±0.0% FS for balanced bridge inputs
Source Current-300 Ω, 5°C Temperature	±0.05nA/°C	Triangular	±0.00025% FS	
Noise (10 KHz)	±0.023%FS rms	Triangular	±0.009% FS	

Standard Uncertainty			±0.07% FS	±0.02% FS
Expanded Uncertainty, 95% Confidence			±0.14% FS	±0.04% FS

3.1.2 NATIONAL INSTRUMENTS PXI-628X MULTIPLEXER/ADC

Common Mode Rejection Ratio, CMRR: 110 dB, Assumed Negligible

Crosstalk, Adjacent Channels, 10 VΔ: -75 dB, ±0.017% FS

Absolute Accuracy: ±0.01 FS, 99.7%

Table 3. Summary for National Instruments Model PXI-628X

PARAMETER	SPECIFICATION, ±3σ	DISTRIBUTION	STANDARD UNCERTAINTY	MITIGATED UNCERTAINTY
Common Mode Rejection Ratio	**110 dB**		Not a factor because of configuration	
Crosstalk, Adjacent Channels (Δ10V)	**-75 dB**	**Normal**	±0.017% FS	±0.00017% FS (using Δ of 0.1V)
Absolute Accuracy	**980 µV**		±0.01% FS	
Standard Uncertainty			±0.02% FS	±0.01% FS
Expanded Uncertainty, 95% Confidence			±0.04% FS	±0.02% FS

The adjacent channel crosstalk specified as -75 dB could be a significant error source. The worst case would be a 20-V difference between two adjacent channels. If so, this would become a 0.35% FS error and would dominate the other error sources. While a 20-V swing seems excessive, a 1-V difference between channels is plausible. In this case, the error would be 10 times that indicated in the above table.

3.1.3 Predicted Measurement Uncertainty for General Purpose Voltage Measurement Channels, 10mV Full Scale

The predicted performance is the combined uncertainties of the Pacific Model 6165 amplifier and the NI multiplexer/ADC and is indicated in Table 4. The computed uncertainty is U_{95} = ±0.146% FS. This exceeds the requirement of U_{95} = ±0.04% FS for the 10mV range. As shown in Tables 2 and 3, there are several methods to mitigate the uncertainty. If all mitigations are implemented, the resultant uncertainty would be U_{95} = ±0.044% FS, which when rounded is considered to meet the requirement of U_{95} = ±0.04% FS.

Table 4. Summary of Standard Uncertainties for General Purpose Voltage Inputs

Equipment Used for General Purpose Voltage Measurements	STANDARD UNCERTAINTY, U_c	MITIGATED STANDARD UNCERTAINTY, U_c
Pacific Instruments Model 6165	±0.07% FS	±0.02% FS
National Instruments PXI-628X MULTIPLEXER/ADC	±0.02% FS	±0.01% FS
Combined Standard Uncertainty	±0.07% FS	±0.022% FS
Expanded Uncertainty, 95%	±0.14% FS	±0.044% FS

3.2 FORCE BALANCE MEASUREMENT DATA ACQUISITION SYSTEM

Figure 2 illustrates a simple functional block diagram of the system for measuring force balances and includes an Agilent reference meter which is used to provide traceability to national standards. As shown, the Pacific Model 6160 provides excitation to the balance gauge and also conditions and amplifies the bridge output signal. A Pacific Model 6165 is used to measure the applied excitation voltage. Both amplifier outputs are input to the National Instruments (NI) multiplexer where they are digitized. The force balance requirement is stated for the ±10-mV FS range, which is considered the critical measurement range.

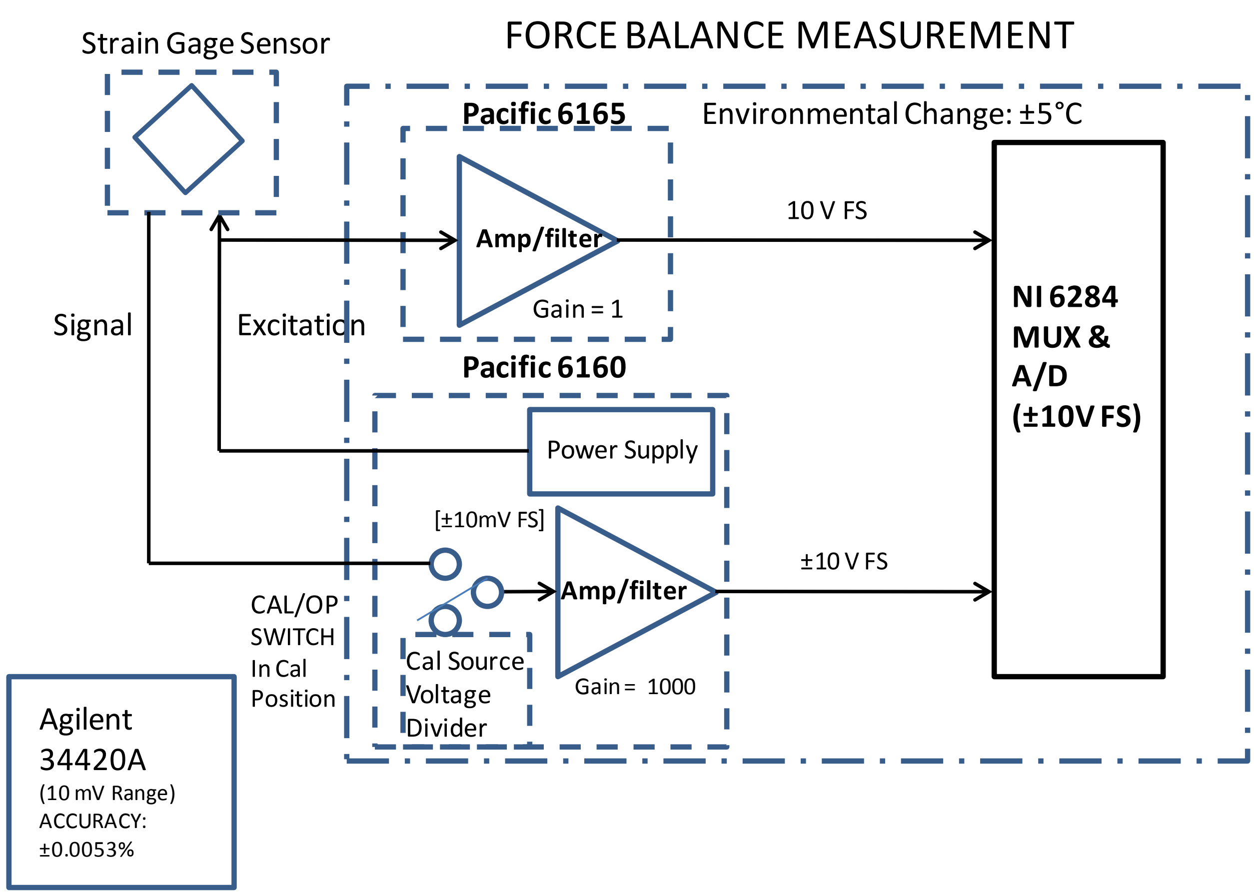

Figure 2. Block Diagram of Force Balance Measurement

3.2.1 Pacific Model 6100/6165 Programmable Instrumentation Amplifiers

This amplifier is used to measure the applied excitation voltage and will be operated on a gain of 1. The specifications are described in Section 3.1.1 and are repeated here only for those specifications that differ as a result of the gain being operated on a gain of 1 rather than a gain of 1,000.

Linearity: ±0.01% FS for gains < 1,000 and ±0.02% FS for gains >1,000. This is assumed to be a random error normally distributed.

Common Mode Rejection Ratio: 60 db plus gain in dB up to 120 dB for balanced input. Assuming a balanced input and using a gain of 1, the common mode is 60 dB. Assuming a common mode of 5V, the common mode error is ±5 mV or ±0.05% FS. For strain-gauge transducers where the common mode voltage is ½ the excitation voltage, this is a systematic error.

Zero: ±2 µV RTI or 0.3 mV RTO. On a gain of 1, this is 0.3 mV or 0.003% FS

Zero Stability, Time: ±5 µV RTI, ±1.0 mV RTO. On a gain of 1, this is ±1 mV or ±0.01% FS. The manufacturer's specification is for 1-year stability and is not indicative of how the system will be operated. Typically, offset and span corrections are performed prior to testing. Accordingly, a 24-hr specification obtained from the manufacturer (±2 µVRTI ±0.4 mVRTO) applies. On a gain of 1, this error is 0.4 mV or ±0.004% FS. This is a random error assumed to be normally distributed.

Zero Stability, Temperature: ±1 µV RTI, ±0.2mV RTO/°C. On a gain of 1 and for a ±5°C change, this is ±1.0 mV or ±0.01% FS. This is a random error with an assumed triangular distribution.

Source Current, Time: ±25 nA. Assuming a source impedance of 300 Ω, this produces an error at the amplifier output of ±25E-06% FS. This is a systematic error.

Source Current, Temperature: ±0.05 nA/°C. Assuming a ±5°C change and a gain of 1, the error at the amplifier output is ±25E-06% FS. This is a systematic error.

Noise (10 kHz): 2.0 µV RTI plus 0.3 mV RTO, RMS. On a gain of 1, this is 0.3 mV or 0.003% FS rms or 0.004%FS peak.

In Table 5, the mitigated uncertainty represents the most probable estimate of uncertainty assuming that (1) gain and zero uncertainties are mitigated to the uncertainty of the Agilent 34420A, (2) the system is routinely rezeroed during operations so a 24-hr zero stability term is more appropriate, and (3) the common mode voltage error for strain-gauge inputs is zeroed out as part of the operational procedure.

Table 5. Summary for Pacific Instruments Model 6100/6165

PARAMETER	SPECIFICATION, ±3σ	DISTRIBUTION	STANDARD UNCERTAINTY	MITIGATED UNCERTAINTY
Gain Accuracy, G=1	±0.05% FS	Normal	±0.017% FS	±0.0011% FS, FS=10V
Gain Stability, Time	±0.02% FS	Normal	±0.007% FS	±0.0% FS. Calibrated out
Gain Stability, 5°C Temperature	±0.025% FS	Triangular	±0.01% FS	
Linearity G=1	±0.01% FS	Normal	±0.003% FS	
Common Mode (5V)	60 dB	Normal	±0.017% FS	±0.0% FS. Zeroed out.
Zero	±0.003% FS	Normal	±0.001% FS	
Zero Stability, 24 hour	±0.004% FS	Normal	±0.001% FS	
Zero Stability, 5°C Temperature	±0.01% FS	Triangular	±0.003% FS	
Source Current-300Ω, Time	±25 nA	Normal	±75E-06% FS	
Source Current-300Ω, 5°C Temperature	±0.05 nA/°C	Triangular	±8E-08% FS	
Noise (10KHz)	±0.004% FS rms	Triangular	±0.002% FS	
Standard Uncertainty			±0.027% FS	±0.011% FS
Expanded Uncertainty, 95% Confidence			±0.055% FS	±0.022% FS

3.2.2 Pacific Model 6100/6160 Programmable Transducer Amplifier

The Model 6160 Programmable Transducer Amplifier is used to interface directly with the strain-gauge balance. The instrument is used to provide excitation voltage or current and is used to condition the balance gauge analog output voltage. The unit is typically operated on either a 5- or 10-mV/FS. For this analysis, the gain is 1,000.

Gain Accuracy: There are 16 different fixed gain steps with an accuracy of ±0.05%FS. This represents a systematic error that can be reduced by computing the actual gain using a known voltage measured by the system reference voltmeter, Agilent 34420A.

Gain Stability, Time: ±0.02% FS for 30 days. Since the system is periodically calibrated in place with zero set, the error is effectively mitigated

Gain Stability, Temperature: ±0.005%/°C. Since the equipment can be exposed to a temperature variation of ±5°C, the stability is the product of these two numbers ±0.025% FS. This is a random error that is assumed to be represented by a triangular distribution.

Linearity: ±0.01% FS for gains < 1,000 and ±0.02% FS for gains >1,000. This is a random error assumed to be normally distributed.

Common Mode Rejection Ratio: 60 db plus gain in dB up to 120 dB for balanced input. Assuming a balanced input and using a gain of 1,000, the common mode is 120 dB. Assuming a common mode of 5 V, the common mode error is 5 µV or 0.00005% FS

Zero: ±2 µV RTI or 0.3 mV RTO. On a gain of 1,000, this is 2.0 mV or 0.02% FS and is a systematic error.

Zero Stability, Time: ±5 µV RTI, ±1.0 mV RTO. On a gain of 1,000, this is ±6 mV or ±0.06% FS. The manufacturer's specification is for 1-year stability and is not indicative of how the system will be operated. Typically, offset and span corrections are performed prior to testing. Accordingly, a 24-hr specification obtained from the manufacturer (±2 µVRTI ±0.4 mVRTO) applies. On a gain of 1,000, this error is ±2.4 mV or ±0.024% FS. This is a random error assumed to be normally distributed.

Zero Stability, Temperature: ±1 µV RTI, ±0.2 mV RTO/°C. On a gain of 1,000 and for a ±5°C change, this is 1.0 mV, ±1.0 mV or ±2 mV or ±0.02% FS. This is a random error with an assumed triangular distribution.

Source Current, Time: ±25 nA. Assuming a source impedance of 350 Ω which is typical for strain-gauge balances at AEDC, this produces an error at the amplifier output of ±0.088% FS. This is a systematic error.

Source Current, Temperature: ±0.05 nA/°C. Assuming a ±5°C change and a gain of 1,000, the error at the amplifier output is ±0.0008% FS.

Noise (10 kHz): 2.0 µV RTI plus 0.3 mV RTO, RMS. On a gain of 1,000, this is 2.3 mV or 0.023% FS rms or 0.032% FS peak.

In Table 6, the mitigated uncertainty represents the most probable estimate of uncertainty assuming that (1) gain and zero uncertainties are mitigated to the uncertainty of the Agilent 34420A, (2) the system is routinely rezeroed during operations so a 24-hr zero stability term is more appropriate, and (3) the common mode voltage error for strain-gauge inputs is zeroed out as part of the operational procedure.

Table 6. Summary for Pacific Instruments Model 6100/6160

PARAMETER	SPECIFICATION, ±3σ	DISTRIBUTION	STANDARD UNCERTAINTY	MITIGATED UNCERTAINTY
Gain Accuracy, G=1000	±0.05% FS	Normal	±0.017% FS	±0.0018% FS. Using Agilent 34420A
Gain Stability, Time	±0.02% FS	Normal	±0.007% FS	±0% FS. Calibrated out
Gain Stability, 5°C Temperature	±0.025% FS	Triangular	±0.01% FS	
Linearity, G=1000	±0.02% FS	Normal	±0.007% FS	
Common Mode (5V)	120 dB	Normal	±0.0002% FS	±0.0% FS. The fixed error is zeroed out for bridge inputs
Zero	±0.02% FS	Normal	±0.007% FS	±0.0018% FS. Using Agilent 34420A
Zero Stability	±0.024% FS	Normal	±0.06% FS	±0.008% FS. Using 24-hr stability
Zero Stability, 5°C Temperature	±0.02% FS	Triangular	±0.008% FS	
Source Current-300Ω, Time	±25 nA	Normal	±0.025% FS	±0.0% FS for balanced bridge inputs
Source Current-300Ω, 5°C Temperature	±0.05nA/°C	Triangular	±0.00025% FS	
Noise (10 KHz)	±0.023% FS rms	Triangular	±0.009% FS	
Standard Uncertainty			±0.07% FS	±0.02% FS
Expanded Uncertainty, 95% Confidence			±0.14% FS	±0.04% FS

3.2.3 National Instruments PXI-628X Multiplexer/ADC

Common Mode Rejection Ratio, CMRR: 110 dB, Assumed Negligible

Crosstalk, Adjacent Channels, 10VΔ: -75 dB, ±0.017% FS

Absolute Accuracy: ±0.01 FS, 99.7%

The errors for the National Instruments Multiplexer/ADC are summarized in Table 7.

Table 7. Summary for National Instruments PXI-628X Multiplexer/ADC

PARAMETER	SPECIFICATION, ±3σ	DISTRIBUTION	STANDARD UNCERTAINTY	MITIGATED UNCERTAINTY
Common Mode Rejection Ratio	**110 dB**		Not a factor because of configuration	
Crosstalk, Adjacent Channels (Δ10V)	**-75 dB**	**Normal**	±0.017% FS	±0.00017% FS
Absolute Accuracy	**980 µV**		±0.01% FS	
Standard Uncertainty			±.02% FS	±0.01% FS
Expanded Uncertainty, 95% Confidence			±0.04% FS	±0.02% FS

3.2.4 Predicted Measurement Uncertainty for Force Balance

The predicted performance is the combined uncertainties of the Pacific Model 6165 instrumentation amplifier (used to measure the excitation voltage), the Pacific Model 6160 Programmable Transducer Amplifier (used to measure the force balance output signal), and the NI multiplexer/ADC. Table 8 summarizes the standard uncertainties for the various equipment used to measure force balance inputs. Using the mitigations identified previously, the projected uncertainty for the force balance channels is U_{95} = ±0.052% FS, which when rounded meets the requirement of U_{95} = ±0.05% FS.

Table 8. Summary of Standard Uncertainties for Force Balance Inputs

FORCE BALANCE EQUIPMENT	STANDARD UNCERTAINTY, U_c	MITIGATED UNCERTAINTY, U_c
Pacific Instruments Model 6165	±0.027% FS	±0.01% FS
National Instruments PXI-628X MULTIPLEXER/ADC	±0.02% FS	±0.01% FS
Pacific Instruments Model 6160	±0.07% FS	±0.02% FS
National Instruments PXI-628X MULTIPLEXER/ADC	±0.02 FS	±0.01 FS
Combined Standard Uncertainty	±0.08% FS	±0.026% FS
Expanded Uncertainty, 95%	±0.16% FS	±0.052% FS

4.0 SUMMARY

Using the various equipment manufacturers' specifications, the measurement uncertainty has been predicted for both the general purpose voltage measurements and the force balance measurements. The analysis identified several significant error sources such as the gain accuracy specification of ±0.05% FS, zero of ±0.02% FS, and zero stability of ±0.024% FS that would prevent the requirements from being met without special action. By understanding the different errors, specific actions such as zero and gain calibrations were identified that enabled the system to meet the requirements.

The methodology described in this paper represents a way of using available information from equipment manufacturers and other sources to estimate or predict the uncertainty. As such, this is an estimate and should be replaced with end-to-end system evaluations.

REFERENCES

1. Assessment of Experimental Uncertainty With Application to Wind Tunnel Testing, S-071A-1999, American Institute of Astronautics and Aeronautics, 1801 Alexander Bell Drive, Suite 500, Reston, VA 20191.

2. Test Uncertainty, ASME PTC 19.1-2005, American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

3. Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results. NIST Technical Note 1297, 1994 Edition. United States Department of Commerce Technology Administration, National Institute of Standards and Technology.

4. Measurement Uncertainty Analysis Principles and Methods, NASA-HDBK-8739.19-3. National Aeronautics and Space Administration, Washington, DC July 2010.

5. International Vocabulary of Metrology—Basic and General Concepts and Associated Terms (VIM). Committee for Guides in Metrology JCGM 200:2008, 3rd Edition, 2008.

APPENDIX A. AGILENT TECHNOLOGIES

Agilent 34420A NanoVolt/Micro-Ohm Meter

Data Sheet

- **7 ½ digits resolution**
- **100pV, 100 nΩ sensitivity**
- **1.3 nVrms, 8 nVpp noise performance**
- **Built-in low noise 2 channel scanner**
- **Direct SPRT, RTD, Thermistor, and Thermocouple measurements**

Nanovolt Performance at a Microvolt Price

The Agilent Technologies 34420A nano-Volt/micro-Ohm meter is a high-sensitivity multimeter optimized for performing low-level measurements. It combines low-noise voltage measurements with resistance and temperature functions, setting a new standard in low-level flexibility and performance.

Take the Uncertainty Out of Your Low-Level Measurements

Low-noise input amplifiers and a highly tuned input protection scheme bring reading noise down to 8 nVpp. Combine this with 7½ digits of resolution, selectable analog and digital filtering, 2 ppm basic 24-hour dcV accuracy, and a shielded, copper pin connector and you've got accurate, repeatable measurements you can count on.

Two Input Channels

An integral two-channel programmable scanner simplifies voltage comparisons. Built-in ratio and difference functions enable automated two channel measurements without the need for an external nanoVolt scanner. Both channels share the same low noise specifications to ensure accurate comparisons.

Built-In Resistance and Temperature

The 34420A combines its low-noise nanoVolt input circuits with a high-stability current source to provide precise low-level resistance measurements – no more hassling with the cost and complexity of an external current source. Three resistance modes are included:

- Standard
- Low-power
- Voltage-limited for dry-circuit testing

Offset compensation is also provided to minimize thermal EMFs and associated errors.

SPRT Measurements

Built-in ITS-90 conversion routines accept the calibration coefficients from your SPRT probe for direct temperature measurement and conversion. Thermocouples, thermistors, and RTDs are also supported.

Unequaled Versatility

The 34420A gives you the versatility to tackle your most challenging tasks, both on the benchtop and in your automated system. Standard features include RS-232 and GPIB interfaces, SCPI and Keithley 181 programming language, 1024-reading memory, scaling and statistics, and a chart recorder analog output.

Agilent IntuiLink:Easy Data Access

The included Agilent IntuiLink software allows your captured data to be put to work easily, using PC applications such as Microsoft Excel® or Word® to analyze, interpret, display, print, and document the data you get from the 34420A. You can specify the meter setup and take a single reading or log data to the Excel spreadsheet in specified time intervals. To find out more about IntuiLink visit **www.agilent.com/find/intuilink**

Quality You Can Count On

The 34420A gives you the quality and reliability you expect from Agilent Technologies. From the product's proven >150,000 hour Mean Time Between Failure, to its standard 1-year warranty, Agilent stands behind you to bring a new level of confidence to your low-level measurements.

Agilent Technologies

Specifications

Accuracy Specifications ±(% of reading + % of range) [1]

Function	Range[2]	Test Current	24 Hour 23 °C ± 1 °C	90 Day 23 °C ± 5 °C	1 Year 23 °C ± 5 °C	Temperature Coefficient 0 °C—18 °C 28 °C—55 °C	Maximum per Lead Resistance
dc Voltage	1.0000000 mV[3]		0.0025 + .0020	0.0040 + .0020	0.0050 + .0020	0.0004 + .0001	
	10.000000 mV[3]		0.0025 + .0002	0.0040 + .0002	0.0050 + .0003	0.0004 + .0001	
	100.00000 mV		0.0015 + .0003	0.0030 + .0004	0.0040 + .0004	0.0004 + .00006	
	1.0000000 V		0.0010 + .0003	0.0025 + .0004	0.0035 + .0004	0.0004 + .00004	
	10.000000 V		0.0002 + .0001	0.0020 + .0004	0.0030 + .0004	0.0001 + .00002	
	100.00000 V[4]		0.0010 + .0004	0.0025 + .0005	0.0035 + .0005	0.0004 + .00005	
Resistance [5]	1.0000000 Ω	10 mA	0.0015 + .0002	0.0050 + .0002	0.0070 + .0002	0.0005 + .00002	1 Ω
	10.000000 Ω	10 mA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	1 Ω
	100.00000 Ω	10 mA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	10 Ω
	1.0000000 KΩ	1 mA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	100 Ω
	10.000000 KΩ	100 µA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	1 KΩ
	100.00000 KΩ	10 µA	0.0015 + .0003	0.0040 + .0004	0.0060 + .0004	0.0005 + .00002	1 KΩ
	1.0000000 MΩ	5 µA	0.0020 + .0003	0.0050 + .0004	0.0070 + .0004	0.0006 + .00003	1 KΩ
Low Power Resistance [5]	1.0000000 Ω	10 mA	0.0015 + .0002	0.0050 + .0002	0.0070 + .0002	0.0005 + .00002	1 Ω
	10.000000 Ω	10 mA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	1 Ω
	100.00000 Ω	1 mA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	10 Ω
	1.0000000 KΩ	100 µA	0.0015 + .0002	0.0040 + .0002	0.0060 + .0002	0.0005 + .00001	100 Ω
	10.000000 KΩ	10 µA	0.0015 + .0004	0.0040 + .0004	0.0060 + .0004	0.0005 + .00001	1 KΩ
	100.00000 KΩ	5 µA	0.0015 + .0012	0.0040 + .0015	0.0060 + .0015	0.0005 + .00003	1 KΩ
	1.0000000 MΩ	5 µA	0.0020 + .0003	0.0050 + .0004	0.0070 + .0004	0.0006 + .00003	1 KΩ
Voltage Limited Resistance [5,6]	10.000000 Ω	1 mA	0.0020 + .0002	0.0050 + .0002	0.0070 + .0002	0.0005 + .00002	1 Ω
	100.00000 Ω	100 µA	0.0025 + .0002	0.0050 + .0002	0.0070 + .0002	0.0005 + .00002	5 Ω

Channel 1 / Channel 2 (dcV Ratio)	Ratio Error in % = Channel 1 accuracy in % + Channel 2 accuracy in %
Channel 1-Channel 2 (dcV Difference)	Difference Error = Channel 1 (% of reading + % of range) + Channel 2 (% of reading + % of range)

Temperature	(resolution = 0.001 °C)	
SPRT [7]		SPRT Probe Accuracy + 0.003°C
RTD		RTD Probe Accuracy + 0.05°C
Thermistor		Thermistor Probe Accuracy + 0.1°C
Thermocouple [8]		Thermocouple Probe Accuracy + 0.2°C

DC Voltage Noise [9]

	Observation Period		
Range	**2-Minute RMS Noise**	**2-Minute Peak-Peak Noise**	**24-Hour Peak-Peak Noise**
1 mV	1.3 nVrms	8 nVpp	12 nVpp
10 mV	1.5 nVrms	10 nVpp	14 nVpp
100 mV	10 nVrms	65 nVpp	80 nVpp
1 V	100 nVrms	650 nVpp	800 nVpp
10 V	450 nVrms	3 µVpp	3.7 µVpp
100 V	11 µVrms	75 µVpp	90 µVpp

DC Voltage Noise vs Source Resistance [10]

Source Resistance	Noise	Analog Filter	Digital Filter
0 Ω	1.3 nVrms	Off	Med
100 Ω	1.7 nVrms	Off	Med
1k Ω	4 nVrms	Off	Med
10k Ω	13 nVrms	Off	Med
100k Ω	41 nVrms	On	Med
1M Ω	90 nVrms	On	Slow

1 Specifications are for Channel 1 or Channel 2, after 2-hour warm-up, resolution at 7.5 digits (100 NPLC), with FILTERS off. RESISTANCE specifications are for 4-wire Ohms or 2-wire ohms using Null. Without Null, add 0.2 Ohms additional error in 2-wire Ohms function. For Analog Filter ON, add 0.002% of reading.
2 20% overrange on all ranges except 5% on Voltage Limited Resistance.
3 After using Math Null. If Null is not used add 100 nanoVolts.
4 Channel 1 only.
5 Channel 1 only. Resistance measurements, for NPLC <1, add 160 µΩ rms noise.
6 Voltage limit can be set to 20 mV (default), 100 mV, or 500 mV. Measured resistance plus Channel 1 HI and LO lead resistance is limited to 10.5 Ω on the 10 Ω range and 105 Ω on the 100 Ω range.
7 For 25 Ω SPRT with triple-point of water check within the last 4 hours. Without the triple-point of water check, add 0.013°C for 24 hours, add 0.035°C for
90 day, and add 0.055°C for 1 year specifications.
8 For fixed reference junction. Add 0.30C for external reference junction, add 2.00C for internal reference junction.
9 After a 2-hour warm-up, ± 10C, 6.5 digits (10 PLC) with Analog Filter Off and Digital Filter Medium (50 reading average).
2-minute rms and 24-hour noise typical. For measurements using 0.02 or 0.2 NPLC, add 800 nV rms noise.
10 Typical noise behavior for Ch 1 or Ch 2, after 2 hour warm-up, 6.5 digits (10 PLC), 2 minute observation period on 1 mV range. For peak-to-peak noise, multiply rms noise by 6.

2

Measurement Characteristics

DC Voltage

Measurement Method:
Continuously integrating multi-slope III A-D Converter

A-D Linearity:
0.00008% of reading + 0.00005% of range

Input Resistance:
100V (Ch1 only): 10 MΩ +- 1%
1mV through 10V: > 10 GΩ, in parallel with < 3.6 nF

Input Bias Current: <50 pA at 25 °C

Injected Current: <50 nA pp at 50 or 60 Hz

Input Protection:
150 V peak any input terminal to Channel 1 LO, continuous

Channel-to-channel switching error (typical):
3 nV

Channel Isolation:
Isolation between input channels >10^{10} Ω

Earth Isolation:
350 V peak any input terminal to earth. Impedance from any input terminal to earth is >10 GΩ and <400 pF

Maximum Voltage:
Channel 1 LO to Channel 2 LO, 150V peak

Resistance

Measurement Method:
Selectable 4-wire or 2-wire ohms. Current Source referenced to Channel 1 LO input

Offset Compensation:
Used on all ranges except 100 kΩ and 1 MΩ. Can be turned off if desired

Protection: 150 V peak

Open Circuit Voltage:
For Resistance and Low Power Resistance <14 V. 20 mV, 100 mV, 500 mV selectable clamp

Temperature

SPRT:
ITS-90 calibrated temperature with the range of -190°C to +660°C

Thermocouple:
ITS-90 conversions of Type B, E, J, K, N, R, S, T

Thermistor: 5 kΩ

RTD: Type α =.00385 and α =.00392. R_0 from 4.9 Ω to 2.1 kΩ. ITS -90 (IEC-751) Callendar Van Dusen conversion.

Measurement Noise Rejection 60 (50) Hz[1]

dc CMRR: 140 dB
ac CMRR: 70 dB

Integration Time	Normal Mode Rejection[2]
200 plc/3.335 s (4 s)	110 dB[3]
100 plc/1.675 s (2 s)	105 dB[3]
20 plc/334 ms (400 ms)	100 dB[3]
10 plc/167 ms (200 ms)	95 dB3
2 plc/33.3 ms (40 ms)	90 dB
1 plc/16.7 ms (20 ms)	60 dB
<1 plc	0

Operating Characteristics[4]

Function	Digits	Integration Time	Readings/s [5]
dcV	7½	200 plc	.15 (.125)
Thermocouple	7½	100 plc	.3 (.25)
	6½	20 plc	1.5 (1.25)
	6½	10 plc	3 (2.5)
	5½	1 plc	25 (20.8)
	5½	0.2 plc	100 (100)
	4½	0.02 plc	250 (250)
Resistance	7½	200 plc	.075 (.062)
dcV1/DCV2	7½	100 plc	.15 (.125)
dcV 1-2	6½	20 plc	.75 (.625)
RTD	6½	10 plc	1.5 (1.25)
Thermistor	5½	1 plc	12.5 (10.4)
0.2 plc	50 (50)		
	41/2		
0.02 plc	125 (125)		

System Speeds[6]

Configuration Rates: 26/s to 50/s
Autorange Rate (Volts): >30/s
ASCII reading to RS-232: 55/s
ASCII reading to GPIB: 250/s
Max. Internal Trigger Rate: 250/s
Max. Ext. Trig. Rate to Memory: 250/s

Triggering and Memory

Reading HOLD Sensitivity:
10%, 1%, 0.1%, or 0.01% of range
Samples/Trigger: 1 to 50,000
Trigger Delay: 0 to 3600 s; 10 µs step size
External Trigger Delay: <1 ms
External Trigger Jitter: <500 µs
Memory: 1024 readings

Math Functions

NULL (Channel 1 dcV, Channel 2 dcV, Difference, Resistance, Temperature)

STATS (Min, Max, Average, Peak-Peak, Standard Deviation, Number of readings)

SCALE (Allows linear scaling as y = mx+b)

CHART NULL (Establishes zero for rear panel output)

Filter (Analog or Digital or Both)

Analog:
Low pass 2 pole @ 13Hz, available for dcV on
1 mV, 10 mV, 100 mV range

Digital:
Moving average filter, 10 (fast), 50 (medium), or 100 (slow) reading averages.

1 For 1 kΩ unbalanced in LO lead.
2 For power line frequency ± - 0.1%, Filters OFF. For Digital Filter slow add 20 db, for medium or fast add 10 db for NPLC ³ 1.
3 For power line frequency ± - 1%, use 80 db, for ± - 3% use 60 db.
4 Speeds are for delay 0, Display OFF, Filters OFF, Offset Compensation OFF.
5 Reading speeds for 60 Hz or (50 Hz), 100 mV through 100 V ranges. 1 mV range 30/s MAX, 10 mV range 170/s MAX, thermocouple 120/s MAX.
6 Speeds are for NPLC 0.02, Delay 0, Display OFF, Chart Out OFF.

Chart Out (Analog Out)

Maximum output: ± 3V

Resolution: 16 bits

Accuracy: ± 0.1% of output + 1 mV

Output Resistance: 1 kΩ ± 5%

Update rate: once per reading

Span and Offset: Adjustable

Standard Programming Languages

SCPI (IEEE 488.2), Keithley 181

Accessories Included

4 ft low thermal cable with copper spade lugs, Kelvin clip set, 4-wire shorting plug, user's manual, service manual, test report, contact cleaner, and power cord.

General Specifications

Front Panel Connection:
Shielded, low thermal, 99% copper contacts.

Power Supply:
100V/120V/220V(230V)/240V +- 10%.

Power Line Frequency:
45 Hz to 66 Hz and 360 Hz to 440 Hz. Automatically sensed at power-on.

Power Consumption:
25VA peak (10W average).

Operating Environment:
Full accuracy for 0 °C to 55 °C. Full accuracy to 80% R.H. up to 30 °C.

Storage Environment:
-40 °C to 75 °C.

Size: 254.4 mm W x 374.0 mm L x 103.6 mm H (10.02" W x 14.72" L x 4.08" H)

Weight: 3 kg (6.5 lbs).

Safety:
Designed to CSA, UL-1244, IEC-1010.
RFI and ESD: CISPR 11.

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Ordering Information

34420A nanoVolt/micro-Ohm meter

Includes low-thermal input cable (34102A), low-thermal shorting plug (34103A), Kelvin clip set (11062A), operating manual, service manual, and quick reference guide, test report with calibration sticker, 2.3 ml bottle of contact cleaner, and power cord.

Options

34420A-1CM Rack mount kit (P/N 5062-3972)
34420A-ABA English localization
34420A-ABD German localization: translated operating manual
34420A-ABF French localization: translated operating manual
34420A-ABJ Japanese localization: translated operating manual
34420A-A6J ANSI Z540 compliant calibration

Accessories

34102A Low-thermal input cable (four-conductor) with copper spade lugs
34103A Low-thermal shorting plug
34104A Low-thermal input connector
34161A Accessory pouch

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Agilent Technologies

APPENDIX B. NATIONAL INSTRUMENTS

NATIONAL INSTRUMENTS

Technical Sales
United States
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Requirements and Compatibility | Ordering Information | Detailed Specifications | Pinouts/Front Panel Connections
For user manuals and dimensional drawings, visit the product page resources tab on ni.com

Last Revised: 2011-10-21 10:31:23.0

High-Accuracy M Series Multifunction DAQ - 18-Bit, up to 625 kS/s, up to 32 Analog Inputs

- 16 or 32 analog inputs at 18 bits, 625 kS/s (500 kS/s scanning)
- Up to 4 analog outputs at 16 bits, 2.8 MS/s (3 µs full-scale settling)
- 7 programmable input ranges (±100 mV to ±10 V) per channel
- Programmable, onboard lowpass filtering
- Up to 48 TTL/CMOS digital I/O lines (up to 32 hardware-timed at 10 MHz)
- Two 32-bit, 80 MHz counter/timers
- Analog and digital triggering
- NI-MCal calibration technology for improved measurement accuracy

Overview

NI M Series high-accuracy multifunction data acquisition (DAQ) devices are optimized for 18-bit analog input accuracy. This resolution is equivalent to 5½ digits for DC measurements. To ensure accuracy, the NI-PGIA 2 amplifier technology is optimized for low noise and fast settling to 18 bits, and the onboard lowpass filter rejects high-frequency noise and prevents aliasing. M Series devices are ideal for applications including test, control, and design. All high-accuracy devices have a minimum of 16 analog inputs, 24 digital I/O lines, seven programmable input ranges, analog and digital triggering, and two counter/timers. They also have an extended two-year calibration interval.

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Requirements and Compatibility

OS Information

- Windows 2000/XP
- Windows Vista x64/x86
- Linux®
- Mac OS X
- Windows 7

Driver Information

- NI-DAQmx
- NI-DAQmx Base

Software Compatibility

- ANSI C
- LabVIEW
- LabWindows/CVI
- Measurement Studio Professional Edition
- Visual Basic
- Visual Studio .NET

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Comparison Tables

Family	Bus	Analog Inputs	AI Resolution (Bits)	Analog Outputs	AO Resolution (Bits)	Max AO Update Rate (MS/s)	AO Range	Digital I/O	Correlated (clocked) DIO
NI 6280	PCI, PXI	16	18	-	-	-	-	24	8, up to 10 MHz
NI 6281	PCI, PXI	16	18	2	16	2.8	Programmable per channel	24	8, up to 10 MHz
NI 6284	PCI, PXI	32	18	-	-	-	-	48	32, up to 10 MHz

Family	Bus	Analog Inputs	AI Resolution (Bits)	Analog Outputs	AO Resolution (Bits)	Max AO Update Rate (MS/s)	AO Range	Digital I/O	Correlated (clocked) DIO
NI 6289	PCI, PXI	32	18	4	16	2.8	Programmable per channel	48	32, up to 10 MHz

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Application and Technology

M Series for Test

For test, you can use M Series high-accuracy analog inputs and 10 MHz digital lines with NI signal conditioning for applications including electronics test, component characterization, and sensor and signal measurements requiring instrument-class accuracy. The 18-bit analog-to-digital converter (ADC) and available filtering provide a 4 times increase in resolution and 5 times more measurement sensitivity. With fast sampling rates and a low noise floor, these devices can accurately acquire dynamic signals. For better noise rejection, the onboard lowpass filters significantly improve device accuracy. Advanced analog clamping circuitry protects the hardware from overvoltage conditions and ensures accurate measurements on nonsaturated channels. High-accuracy M Series devices are compatible with NI SCC and SCXI signal conditioning platforms, which provide amplification, filtering, and power for virtually every type of sensor. These platforms also are compliant with IEEE 1451.4 smart transducer electronic data sheet (TEDS) sensors, which offer digital storage for sensor data sheet information.

M Series for Control

M Series digital lines can drive 24 mA for relay and actuator control. By clocking the digital lines as fast as 10 MHz, you can use these lines for pulse-width modulation (PWM) to control valves, motors, fans, lamps, and pumps. With four waveform analog outputs, two 80 MHz counter/timers, and six DMA channels, M Series devices can execute multiple control loops simultaneously. The analog outputs on the high-accuracy M Series devices can generate up to 2.86 MS/s and provide user-defined programmable offsets and ranges for maximum waveform resolution over any custom range. High-accuracy M Series devices also have direct support for encoder measurements, protected digital lines, and digital debounce filters for control applications. With up to 32 analog inputs, 32 clocked digital lines, and four analog outputs, you can execute multiple control loops with a single device. For higher-count control loops, you can use M Series devices in conjunction and tightly synchronized with National Instruments analog output devices for 64 or more loops. With the NI SoftMotion Development Module for LabVIEW, you can create a complete custom motion controller with M Series devices.

M Series for Design

For design applications, you can use the wide range of I/O - from 32 analog inputs to 48 digital lines - to measure and verify prototype designs. M Series devices and NI LabVIEW SignalExpress interactive measurement software deliver benchtop measurements to the PC. With LabVIEW SignalExpress interactive configuration-based steps, you can quickly create design verification tests. The fast acquisition and generation rates of high-speed M Series devices along with LabVIEW SignalExpress provide on-the-fly design analysis. You can convert your tested and verified LabVIEW SignalExpress projects to LabVIEW applications for immediate M Series DAQ use and bridge the gap between test, control, and design applications.

Hybrid-Slot-Compatible PXI Modules

M Series modules for PXI are hybrid-slot-compatible so that you can use them in both PXI slots and the hybrid slots found in new PXI Express chassis. The PXI Systems Alliance specifies that hybrid-slot-compatible PXI modules use modified slot connectors to mechanically fit in both PXI slots and hybrid slots. This mechanical change:

- Provides compatibility with past, current, and future PXI chassis
- Maintains existing product specifications
- Requires no software changes (application or driver)
- Maintains speed and capability of all PXI communication (PXI Express signaling is not provided)

However, hybrid-slot-compatible PXI modules do not include the pins used to implement PXI local bus communication, which is used for backplane SCXI control from the right-most PXI slot in PXI/SCXI combination chassis (NI PXI-1010, PXI-1011, PXI-1050, and PXI-1052). For these applications, NI provides unmodified M Series PXI modules that maintain the required local bus capabilities. Refer to the SCXI Control of PXI/SCXI Combination Chassis section in the Ordering Information section for part numbers.

Simultaneous and Intelligent Data Acquisition

When you need to obtain performance from a data acquisition device beyond the capabilities of a multifunction DAQ device, National Instruments provides simultaneous sampling with the S Series and intelligent DAQ with the R Series. The S Series architecture dedicates an ADC per channel to provide higher aggregate sampling rates compared to multiplexed devices. S Series devices are ideal for applications including IF digitization, transient recording, ultrasound and sonar testing, and high-energy physics.

R Series multifunction DAQ devices contain a 1M/3M gate field-programmable gate array (FPGA) that is reconfigurable using the NI LabVIEW FPGA Module. These devices have up to eight independent 16-bit analog inputs with up to 200 kHz simultaneous sampling, up to eight independent 16-bit analog outputs with up to 1 MHz simultaneous update rates, and up to 96 digital I/O lines configurable at rates up to 40 MHz. You can customize these devices to develop capabilities such as complete control over the synchronization and timing of all signals and operations; user-defined onboard decision-making logic; and digital lines individually configurable as input, output, counter/timers, PWM, flexible encoder inputs, or user-defined communication protocols.

Signal Conditioning

Signal conditioning is required for sensor measurements or voltage inputs greater than 10 V. NI SCXI is a versatile, high-performance signal conditioning platform, optimized for high-channel-count applications. NI SCC provides portable, flexible signal conditioning options on a per-channel basis. Visit **ni.com/sigcon** for resources on available NI signal conditioning.

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Ordering Information

For a complete list of accessories, visit the product page on ni.com.

Products	Part Number	Recommended Accessories	Part Number
NI PCI-6280			

NI PCI-6280 Each NI PCI-6280 requires: 1 Cable, 1 Connector Block	779108-01	**Cable:** Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PXI-6280			
NI PXI-6280 Each NI PXI-6280 requires: 1 Cable, 1 Connector Block	779120-01	**Cable:** Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PCI-6281			
NI PCI-6281 Each NI PCI-6281 requires: 1 Cable, 1 Connector Block	779109-01	**Cable:** Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PXI-6281			
NI PXI-6281 Each NI PXI-6281 requires: 1 Cable, 1 Connector Block	779121-01	**Cable:** Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PCI-6284			
NI PCI-6284 Each NI PCI-6284 requires: 2 Cables, 2 Connector Blocks	779110-01	**Connector 0:**	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
		Connector 1:	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PXI-6284			
NI PXI-6284 Each NI PXI-6284 requires: 2 Cables, 2 Connector Blocks	779122-01	**Connector 0:**	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
		Connector 1:	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PCI-6289			
NI PCI-6289 Each NI PCI-6289 requires: 2 Cables, 2 Connector Blocks	779111-01	**Connector 0:**	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68	776844-01

		***Also available: BNC Termination*	
		Connector 1:	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PXI-6289			
NI PXI-6289 Each NI PXI-6289 requires: 2 Cables, 2 Connector Blocks	779639-01	**Connector 0:**	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
		Connector 1:	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
NI PXI-6289 for SCXI Control in PXI/SCXI Combination Chassis Each NI PXI-6289 for SCXI Control in PXI/SCXI Combination Chassis requires: 2 Cables, 2 Connector Blocks	779123-01	**Connector 0:**	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01
		Connector 1:	
		Cable: Shielded - SHC68-68-EPM Cable (2m) ***Also available: Unshielded*	192061-02
		Connector Block: Screw Terminals - SCB-68 ***Also available: BNC Termination*	776844-01

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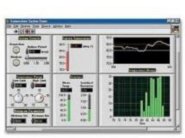
Software Recommendations

LabVIEW Professional Development System for Windows



- Advanced software tools for large project development
- Automatic code generation using DAQ Assistant and Instrument I/O Assistant
- Tight integration with a wide range of hardware
- Advanced measurement analysis and digital signal processing
- Open connectivity with DLLs, ActiveX, and .NET objects
- Capability to build DLLs, executables, and MSI installers

NI LabVIEW SignalExpress for Windows

- Quickly configure projects without programming
- Control over 400 PC-based and stand-alone instruments
- Log data from more than 250 data acquisition devices
- Perform basic signal processing, analysis, and file I/O
- Scale your application with automatic LabVIEW code generation
- Create custom reports or easily export data to LabVIEW, DIAdem or Microsoft Excel

NI LabWindows™/CVI for Windows

- Real-time advanced 2D graphs and charts
- Complete hardware compatibility with IVI, VISA, DAQ, GPIB, and serial
- Analysis tools for array manipulation, signal processing statistics, and curve fitting
- Simplified cross-platform communication with network variables
- Measurement Studio .NET tools (included in LabWindows/CVI Full only)

NI Measurement Studio Professional Edition

- Support for Microsoft Visual Studio .NET 2010/2008/2005
- Customizable Windows Forms and Web Forms controls for test and measurement user interface design
- Hardware integration support with data acquisition and instrument control libraries
- Automatic code generation with data acquisition, instrument control, and parameter assistants

The mark LabWindows is used under a license from Microsoft Corporation.

Cross-platform communication with network variables

- Analysis libraries for array operations, signal generation, windowing, filters, signal processing

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Support and Services

System Assurance Programs

NI system assurance programs are designed to make it even easier for you to own an NI system. These programs include configuration and deployment services for your NI PXI, CompactRIO, or Compact FieldPoint system. The NI Basic System Assurance Program provides a simple integration test and ensures that your system is delivered completely assembled in one box. When you configure your system with the NI Standard System Assurance Program, you can select from available NI system driver sets and application development environments to create customized, reorderable software configurations. Your system arrives fully assembled and tested in one box with your software preinstalled. When you order your system with the standard program, you also receive system-specific documentation including a bill of materials, an integration test report, a recommended maintenance plan, and frequently asked question documents. Finally, the standard program reduces the total cost of owning an NI system by providing three years of warranty coverage and calibration service. Use the online product advisors at ni.com/advisor to find a system assurance program to meet your needs.

Calibration

NI measurement hardware is calibrated to ensure measurement accuracy and verify that the device meets its published specifications. NI offers a number of calibration services to help maintain the ongoing accuracy of your measurement hardware. These services allow you to be completely confident in your measurements, and help you maintain compliance to standards like ISO 9001, ANSI/NCSL Z540-1 and ISO/IEC 17025. To learn more about NI calibration services or to locate a qualified service center near you, contact your local sales office or visit ni.com/calibration.

Technical Support

Get answers to your technical questions using the following National Instruments resources.

- **Support** - Visit ni.com/support to access the NI KnowledgeBase, example programs, and tutorials or to contact our applications engineers who are located in NI sales offices around the world and speak the local language.
- **Discussion Forums** - Visit forums.ni.com for a diverse set of discussion boards on topics you care about.
- **Online Community** - Visit community.ni.com to find, contribute, or collaborate on customer-contributed technical content with users like you.

Repair

While you may never need your hardware repaired, NI understands that unexpected events may lead to necessary repairs. NI offers repair services performed by highly trained technicians who quickly return your device with the guarantee that it will perform to factory specifications. For more information, visit ni.com/repair.

Training and Certifications

The NI training and certification program delivers the fastest, most certain route to increased proficiency and productivity using NI software and hardware. Training builds the skills to more efficiently develop robust, maintainable applications, while certification validates your knowledge and ability.

- **Classroom training in cities worldwide** - the most comprehensive hands-on training taught by engineers.
- **On-site training at your facility** - an excellent option to train multiple employees at the same time.
- **Online instructor-led training** - lower-cost, remote training if classroom or on-site courses are not possible.
- **Course kits** - lowest-cost, self-paced training that you can use as reference guides.
- **Training memberships** and training credits - to buy now and schedule training later.

Visit ni.com/training for more information.

Extended Warranty

NI offers options for extending the standard product warranty to meet the life-cycle requirements of your project. In addition, because NI understands that your requirements may change, the extended warranty is flexible in length and easily renewed. For more information, visit ni.com/warranty.

OEM

NI offers design-in consulting and product integration assistance if you need NI products for OEM applications. For information about special pricing and services for OEM customers, visit ni.com/oem.

Alliance

Our Professional Services Team is comprised of NI applications engineers, NI Consulting Services, and a worldwide National Instruments Alliance Partner program of more than 600 independent consultants and integrators. Services range from start-up assistance to turnkey system integration. Visit ni.com/alliance.

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Detailed Specifications

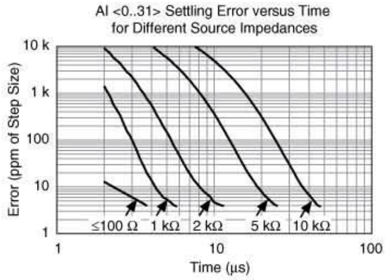
Specifications listed below are typical at 25 °C unless otherwise noted. Refer to the *M Series User Manual* for more information about NI 628x devices.

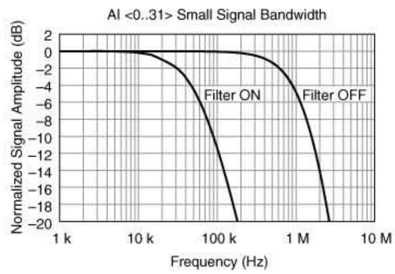
Analog Input	
Number of channels	
NI 6280/6281	8 differential or 16 single ended
NI 6284/6289	16 differential or 32 single ended
ADC resolution	18 bits
DNL	No missing codes guaranteed
INL	Refer to the *AI Absolute Accuracy Tables*
Sampling rate	
Maximum	625 kS/s single channel, 500 kS/s multi-channel (aggregate)
Minimum	No minimum
Timing accuracy	50 ppm of sample rate
Timing resolution	50 ns
Input coupling	DC
Input range	±10 V, ±5 V, ± 2 V, ±1 V, ±0.5 V, ± 0.2 V, ± 0.1 V
Maximum working voltage for analog inputs (signal + common mode)	±11 V of AI GND
CMRR (DC to 60 Hz)	110 dB
Input impedance	
Device on	
AI+ to AI GND	>10 GΩ in parallel with 100 pF
AI- to AI GND	>10 GΩ in parallel with 100 pF
Device off	
AI+ to AI GND	820 Ω
AI- to AI GND	820 Ω
Input bias current	±100 pA
Crosstalk (at 100 kHz)	
Adjacent channels	-75 dB
Non-adjacent channels	-95 dB
Small signal bandwidth (-3 dB)	750 kHz filter off, 40 kHz filter on
Input FIFO size	2,047 samples
Scan list memory	4,095 entries
Data transfers	
PCI/PXI devices	DMA (scatter-gather), interrupts, programmed I/O
USB devices	USB Signal Stream, programmed I/O
Overvoltage protection (AI <0..31>, AI SENSE, AI SENSE 2)	
Device on	±25 V for up to eight AI pins
Device off	±15 V for up to eight AI pins
Input current during overvoltage condition	±20 mA max/AI pin

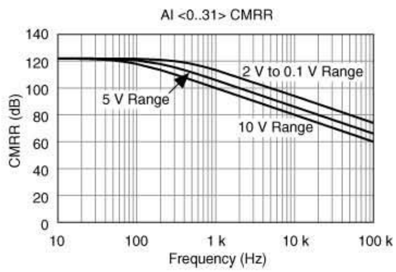
Settling Time for Multichannel Measurements

Range	Filter Off		Filter On
	±15 ppm of Step (±4 LSB for Full Scale Step)	±4 ppm of Step (±1 LSB for Full Scale Step)	±4 ppm of Step (±1 LSB for Full Scale Step)
±10 V, ±5 V	2 μs	8 μs	50 μs
±2 V, ±1 V, ±0.5 V	2.5 μs	8 μs	50 μs
±0.2 V, ±0.1 V	3 μs	8 μs	50 μs

Typical Performance Graphs







Analog Triggers	
Number of triggers	1
Source	
NI 6280/6281	AI <0..15>, APFI 0
NI 6284/6289	AI <0..31>, APFI <0..1>
Functions	Start Trigger, Reference Trigger, Pause Trigger, Sample Clock, Convert Clock, Sample Clock Timebase
Source level	
AI <0..31>	±Full scale
APFI <0..1>	±10 V
Resolution	10 bits, 1 in 1024
Modes	Analog edge triggering, analog edge triggering with hysteresis, and analog window triggering
Bandwidth (-3 dB)	
AI <0..31>	700 kHz filter off, 40 kHz filter on
APFI <0..1>	5 MHz
Accuracy	±1%
APFI <0..1> characteristics	
Input impedance	10 kΩ
Coupling	DC
Protection	
Power on	±30 V
Power off	±15 V

Analog Output

Number of channels	
NI 6280/6284	0
NI 6281	2
NI 6289	4
DAC resolution	16 bits
DNL	±1 LSB
Monotonicity	16 bit guaranteed
Accuracy	Refer to the *AO Absolute Accuracy Table*
Maximum update rate	
1 channel	2.86 MS/s
2 channels	2.00 MS/s
3 channels	1.54 MS/s
4 channels	1.25 MS/s
Timing accuracy	50 ppm of sample rate
Timing resolution	50 ns
Output range	Offset ± reference, includes ±10 V, ±5 V, ±2 V, and ±1 V calibrated ranges
Offset	0 V, 5 V, APFI <0..1>, AO <0..3>[1]
Reference	10 V, 5 V, 2 V, 1 V, APFI <0..1>, AO <0..3>[1]
Maximum output level	±11 V
Output coupling	DC
Output impedance	0.2 Ω
Output current drive	±5 mA
Overdrive protection	±25 V
Overdrive current	20 mA
Power-on state	±5 mV[2]
Power-on glitch	2.3 V peak for 1.2 s
Output FIFO size	8,191 samples shared among channels used
Data transfers	
PCI/PXI devices	DMA (scatter-gather), interrupts, programmed I/O
USB devices	USB Signal Stream, programmed I/O

AO waveform modes:

- Non-periodic waveform
- Periodic waveform regeneration mode from onboard FIFO
- Periodic waveform regeneration from host buffer including dynamic update

Settling time, full scale step 15 ppm (1 LSB)	3 µs
Slew rate	20 V/µs
Glitch energy at midscale transition, ±10 V range	
Magnitude	15 mV
Duration	0.5 µs

[1] An AO channel cannot be a reference or offset to itself.

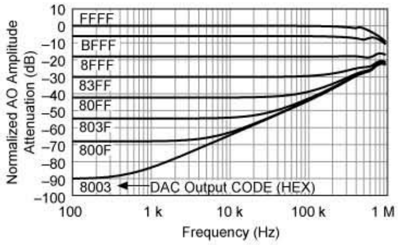
[2] For all USB-6281/6289 Screw Terminal devices, when powered on, the analog output signal is not defined until after USB configuration is complete.

External Reference

APFI <0..1> characteristics	
Input impedance	10 kΩ
Coupling	DC
Protection	

Power on	±30 V
Power off	±15 V
Range	±11 V

AO <0..3> Analog Output External Reference Bandwidth



Calibration (AI and AO)

Recommended warm-up time	
PCI/PXI devices	15 minutes
USB devices	30 minutes
Calibration interval	2 years

AI Absolute Accuracy Table (Filter On)

Nominal Range: Positive Full Scale	Nominal Range: Negative Full Scale	Residual Gain Error (ppm of Reading)	Gain Tempco (ppm/°C)	Reference Tempco	Residual Offset Error (ppm of Range)	Offset Tempco (ppm of Range/°C)	INL Error (ppm of Range)	Random Noise, σ (μVrms)	Absolute Accuracy at Full Scale[1] (μV)	Sensitivity[2] (μV)
10	-10	40	17	1	8	11	10	60	980	24
5	-5	45	17	1	8	11	10	30	510	12
2	-2	45	17	1	8	13	10	12	210	4.8
1	-1	55	17	1	15	15	10	7	120	2.8
0.5	-0.5	55	17	1	30	20	10	4	70	1.6
0.2	-0.2	75	17	1	45	35	10	3	39	1.2
0.1	-0.1	120	17	1	60	60	10	2	28	0.8

Accuracies listed are valid for up to two years from the device external calibration.

AbsoluteAccuracy = Reading · (GainError) + Range · (OffsetError) + NoiseUncertainty

GainError = ResidualAIGainError + GainTempco · (TempChangeFromLastInternalCal) + ReferenceTempco · (TempChangeFromLastExternalCal)

OffsetError = ResidualAIOffsetError + OffsetTempco · (TempChangeFromLastInternalCal) + INL_Error

$$\text{NoiseUncertainty} = \frac{\text{RandomNoise} \cdot 3}{\sqrt{100}}$$ For a coverage factor of 3 σ and averaging 100 points.

[1] Absolute accuracy at full scale on the analog input channels is determined using the following assumptions:

TempChangeFromLastExternalCal = 10 °C

TempChangeFromLastInternalCal = 1 °C

number_of_readings = 100

CoverageFactor = 3 σ

For example, on the 10 V range, the absolute accuracy at full scale is as follows:

GainError = 40 ppm + 17 ppm · 1 + 1 ppm · 10 GainError = 67 ppm

OffsetError = 8 ppm + 11 ppm · 1 + 10 ppm OffsetError = 29 ppm

$$\text{NoiseUncertainty} = \frac{60\ \mu\text{V} \cdot 3}{\sqrt{100}} \qquad \text{NoiseUncertainty} = 18\ \mu\text{V}$$

AbsoluteAccuracy = 10 V · (GainError) + 10 V · (OffsetError) + NoiseUncertainty AbsoluteAccuracy = 980 μV

[2] Sensitivity is the smallest voltage change that can be detected. It is a function of noise.

AI Absolute Accuracy Table (Filter Off)

Nominal Range		Residual Gain Error (ppm of Reading)	Gain Tempco (ppm/°C)	Reference Tempco	Residual Offset Error (ppm of Range)	Offset Tempco (ppm of Range/°C)	INL Error (ppm of Range)	Random Noise, σ (μVrms)	Absolute Accuracy at Full Scale[1] (μV)	Sensitivity[2] (μV)
Positive Full Scale	Negative Full Scale									
10	-10	45	17	1	10	11	10	70	1050	28.0
5	-5	50	17	1	10	11	10	35	550	14.0
2	-2	50	17	1	10	13	10	15	230	6.0
1	-1	60	17	1	17	15	10	12	130	4.8
0.5	-0.5	60	17	1	32	20	10	10	80	4.0
0.2	-0.2	80	17	1	47	35	10	9	43	3.6
0.1	-0.1	120	17	1	62	60	10	9	31	3.6

Accuracies listed are valid for up to two years from the device external calibration.

AbsoluteAccuracy = Reading · (GainError) + Range · (OffsetError) + NoiseUncertainty

GainError = ResidualAIGainError + GainTempco · (TempChangeFromLastInternalCal) + ReferenceTempco · (TempChangeFromLastExternalCal)

OffsetError = ResidualAIOffsetError + OffsetTempco · (TempChangeFromLastInternalCal) + INL_Error

$$\text{NoiseUncertainty} = \frac{\text{RandomNoise} \cdot 3}{\sqrt{100}}$$ For a coverage factor of 3 σ and averaging 100 points.

[1] Absolute accuracy at full scale on the analog input channels is determined using the following assumptions:

TempChangeFromLastExternalCal = 10 °C

TempChangeFromLastInternalCal = 1 °C

number_of_readings = 100

CoverageFactor = 3 σ

For example, on the 10 V range, the absolute accuracy at full scale is as follows:

GainError = 45 ppm + 17 ppm · 1 + 1 ppm · 10 GainError = 72 ppm

OffsetError = 10 ppm + 11 ppm · 1 + 10 ppm OffsetError = 31 ppm

$$\text{NoiseUncertainty} = \frac{70\ \mu\text{V} \cdot 3}{\sqrt{100}} \qquad \text{NoiseUncertainty} = 21\ \mu\text{V}$$

AbsoluteAccuracy = 10 V · (GainError) + 10 V · (OffsetError) + NoiseUncertainty AbsoluteAccuracy = 1050 μV

[2] Sensitivity is the smallest voltage change that can be detected. It is a function of noise.

AO Absolute Accuracy Table

Nominal Range		Residual Gain Error (ppm of Reading)	Gain Tempco (ppm/°C)	Reference Tempco	Residual Offset Error (ppm of Range)	Offset Tempco (ppm of Range/°C)	INL Error (ppm of Range)	Absolute Accuracy at Full Scale[1] (μV)
Positive Full Scale	Negative Full Scale							
10	-10	55	15	1	30	12	32	1540
5	-5	60	15	1	30	17	32	820
2	-2	65	25	1	40	30	32	404
1	-1	85	25	1	57	50	32	259

[1] Absolute Accuracy at full scale numbers is valid immediately following internal calibration and assumes the device is operating within 10 °C of the last external calibration.
Accuracies listed are valid for up to two years from the device external calibration.

AbsoluteAccuracy = OutputValue · (GainError) + Range · (OffsetError)

GainError = ResidualGainError + GainTempco · (TempChangeFromLastInternalCal) + ReferenceTempco · (TempChangeFromLastExternalCal)

OffsetError = ResidualOffsetError + AOOffsetTempco · (TempChangeFromLastInternalCal) + INL_Error

Digital I/O/PFI

Static Characteristics

Number of channels	
NI 6280/6281	24 total 8 (P0.<0..7>) 16 (PFI <0..7>/P1, PFI <8..15>/P2)

NI 6284/6289	48 total 32 (P0.<0..31>) 16 (PFI <0..7>/P1, PFI <8..15>/P2)
I/O type	5 V TTL/CMOS compatible
Ground reference	D GND
Direction control	Each terminal individually programmable as input or output
Pull-down resistor	50 kΩ typical, 20 kΩ minimum
Input voltage protection[3]	±20 V on up to two pins

[3] Stresses beyond those listed under *Input voltage protection* may cause permanent damage to the device.

Waveform Characteristics (Port 0 Only)	
Terminals used	
NI 6280/6281	Port 0 (P0.<0..7>)
NI 6284/6289	Port 0 (P0.<0..31>)
Port/sample size	
NI 6280/6281	Up to 8 bits
NI 6284/6289	Up to 32 bits
Waveform generation (DO) FIFO	2,047 samples
Waveform acquisition (DI) FIFO	2,047 samples
DI Sample Clock frequency	
PCI/PXI devices	0 to 10 MHz[4]
USB devices	0 to 1 MHz system dependent[4]
DO Sample Clock frequency	
PCI/PXI devices	
Regenerate from FIFO	0 to 10 MHz
Streaming from memory	0 to 10 MHz system dependent[4]
USB devices	
Regenerate from FIFO	0 to 10 MHz
Streaming from memory	0 to 1 MHz system dependent[4]
Data transfers	
PCI/PXI devices	DMA (scatter-gather), interrupts, programmed I/O
USB devices	USB Signal Stream, programmed I/O
DO or DI Sample Clock source[5]	Any PFI, RTSI, AI Sample or Convert Clock, AO Sample Clock, Ctr *n* Internal Output, and many other signals

[4] Performance can be dependent on bus latency and volume of bus activity.

[5] The digital subsystem does not have its own dedicated internal timing engine. Therefore, a sample clock must be provided from another subsystem on the device or an external source.

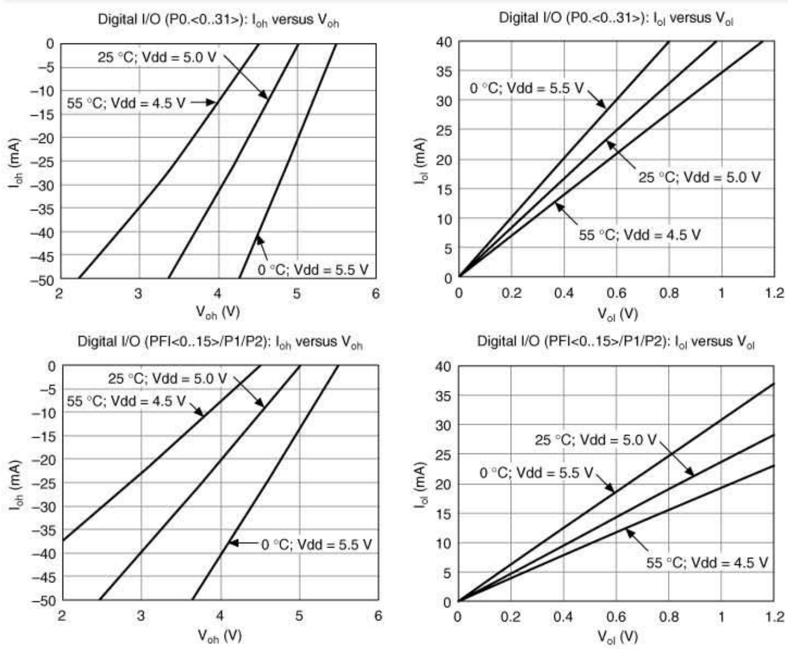
PFI/Port 1/Port 2 Functionality	
Functionality	Static digital input, static digital output, timing input, timing output
Timing output sources	Many AI, AO, counter, DI, DO timing signals
Debounce filter settings	125 ns, 6.425 µs, 2.56 ms, disable; high and low transitions; selectable per input

Recommended Operation Conditions

Level	Min	Max
Input high voltage (V_{IH})	2.2 V	5.25 V
Input low voltage (V_{IL})	0 V	0.8 V
Output high current (I_{OH}) P0.<0..31> PFI <0..15>/P1/P2	 — —	 -24 mA -16 mA
Output low current (I_{OL}) P0.<0..31> PFI <0..15>/P1/P2	 — —	 24 mA 16 mA

Electrical Characteristics		
Level	**Min**	**Max**
Positive-going threshold (VT+) Negative-going threshold (VT-)	— 0.8 V	2.2 V —
Delta VT hysteresis (VT+ - VT-)	0.2 V	—
I_{IL} input low current (V_{in} = 0 V)	—	-10 µA
I_{IH} input high current (V_{in} = 5 V)	—	250 µA

Digital I/O Characteristics



General-Purpose Counter/Timers	
Number of counter/timers	2
Resolution	32 bits
Counter measurements	Edge counting, pulse, semi-period, period, two-edge separation
Position measurements	X1, X2, X4 quadrature encoding with Channel Z reloading; two-pulse encoding
Output applications	Pulse, pulse train with dynamic updates, frequency division, equivalent time sampling
Internal base clocks	80 MHz, 20 MHz, 0.1 MHz
External base clock frequency	0 MHz to 20 MHz
Base clock accuracy	50 ppm
Inputs	Gate, Source, HW_Arm, Aux, A, B, Z, Up_Down
Routing options for inputs	Any PFI, RTSI, PXI_TRIG, PXI_STAR, analog trigger, many internal signals
FIFO	2 samples
Data transfers	

PCI/PCIe/PXI/PXIe devices	Dedicated scatter-gather DMA controller for each counter/timer; interrupts, programmed I/O
USB devices	USB Signal Stream, programmed I/O
Frequency Generator	
Number of channels	1
Base clocks	10 MHz, 100 kHz
Divisors	1 to 16
Base clock accuracy	50 ppm
Output can be available on any PFI or RTSI terminal.	
Phase-Locked Loop (PLL) (PCI/PXI Devices Only)	
Number of PLLs	1
Reference signal	PXI_STAR, PXI_CLK10, RTSI <0..7>
Output of PLL	80 MHz Timebase; other signals derived from 80 MHz Timebase including 20 MHz and 100 kHz Timebases
External Digital Triggers	
Source	Any PFI, RTSI, PXI_TRIG, PXI_STAR
Polarity	Software-selectable for most signals
Analog input function	Start Trigger, Reference Trigger, Pause Trigger, Sample Clock, Convert Clock, Sample Clock Timebase
Analog output function	Start Trigger, Pause Trigger, Sample Clock, Sample Clock Timebase
Counter/timer functions	Gate, Source, HW_Arm, Aux, A, B, Z, Up_Down
Digital waveform generation (DO) function	Sample Clock
Digital waveform acquisition (DI) function	Sample Clock
Device-To-Device Trigger Bus	
PCI devices	RTSI <0..7>[6]
PXI devices	PXI_TRIG <0..7>, PXI_STAR
USB devices	None
Output selections	10 MHz Clock; frequency generator output; many internal signals
Debounce filter settings	125 ns, 6.425 µs, 2.56 ms, disable; high and low transitions; selectable per input

[6] In other sections of this document, *RTSI* refers to RTSI <0..7> for PCI devices or PXI_TRIG <0..7> for PXI devices.

Bus Interface	
PCI/PXI devices	3.3 V or 5 V signal environment
USB devices	USB 2.0 Hi-Speed or full-speed[7,8]
DMA channels (PCI/PXI devices)	6, analog input, analog output, digital input, digital output, counter/timer 0, counter/timer 1
USB Signal Stream (USB devices)	4, can be used for analog input, analog output, digital input, digital output, counter/timer 0, counter/timer 1

All PXI-628*x* devices support one of the following features:

- May be installed in PXI Express hybrid slots
- Or, may be used to control SCXI in PXI/SCXI combo chassis

Table 1. PXI/SCXI Combo and PXI Express Chassis Compatibility

M Series Device	M Series Part Number	SCXI Control in PXI/SCXI Combo Chassis	PXI Express Hybrid Slot Compatible
PXI-6280	191501C-04	No	Yes
PXI-6281	191501C-03	No	Yes
PXI-6284	191501C-02	No	Yes

PXI-6289	191501C-01	No	Yes
	191501C-11	Yes	No
Earlier versions of PXI-628*x*	191501A-0*x* 191501B-0*x*	Yes	No

[7] If you are using a USB M Series device in full-speed mode, device performance will be lower and you will not be able to achieve maximum sampling/update rates.
[8] Operating on a full-speed bus may result in lower performance.

Power Requirements

PCI/PXI devices	
Current draw from bus during no-load condition[9]	
+5 V	0.03 A
+3.3 V	0.78 A
+12 V	0.40 A
-12 V	0.06 A
PCI/PXI devices	
Current draw from bus during AI and AO overvoltage condition[9]	
+5 V	0.03 A
+3.3 V	1.26 A
+12 V	0.43 A
-12 V	0.06 A

Caution USB-628*x* devices *must* be powered with NI offered AC adapter or a National Electric Code (NEC) Class evice and has appropriate safety certification marks for country of use.

USB devices	
Power supply requirements	11 to 30 VDC, 20 W, locking or non-locking power jack with 0.080 in. diameter center pin, 5/16-32 thread for locking collars
Power supply fuse	2 A, 250 V

[9] Does not include P0/PFI/P1/P2 and +5 V terminals.

Power Limits

Caution Exceeding the power limits may cause unpredictable behavior by the device and/or PC/chassis.

PCI devices	
+5 V terminal (connector 0)	1 A max[10]
+5 V terminal (connector 1)	1 A max[10]
PXI devices	
+5 V terminal (connector 0)	1 A max[10]
+5 V terminal (connector 1)	1 A max[10]
P0/PFI/P1/P2 and +5 V terminals combined	2 A max
USB devices	
+5 V terminal	1 A max[11]
P0/PFI/P1/P2 and +5 V terminals combined	2 A max

[10] Older revisions have a self-resetting fuse that opens when current exceeds this specification. Newer revisions have a traditional fuse that opens when current exceeds this specification. This fuse is not customer-replaceable; if the fuse permanently opens, return the device to NI for repair.
[11] Has a self-resetting fuse that opens when current exceeds this specification.

Physical Requirements

Printed circuit board dimensions	
NI PCI-6280/6281/6284/6289	10.6 cm x 15.5 cm (4.2 in. x 6.1 in.)
NI PXI-6280/6281/6284/6289	Standard 3U PXI
Enclosure dimensions (includes connectors)	

NI USB-6281/6289 Mass Termination	18.8 x 17.09 x 4.45 cm (7.4 x 6.73 x 1.75 in.)
NI USB-6281/6289 Screw Terminal	26.67 x 17.09 x 4.45 cm (10.5 x 6.73 x 1.75 in.)
NI USB-6258/6289 OEM	Refer to the *NI USB-622x/625x/628x OEM User Guide*
Weight	
NI PCI-6280	151 g (5.3 oz)
NI PCI-6281	158 g (5.6 oz)
NI PCI-6284	159 g (5.6 oz)
NI PCI-6289	167 g (5.9 oz)
NI PXI-6280	218 g (7.7 oz)
NI PXI-6281	225 g (7.9 oz)
NI PXI-6284	229 g (8.1 oz)
NI PXI-6289	237 g (8.4 oz)
NI USB-6281 Mass Termination	1.04 kg (2 lb 4.5 oz)
NI USB-6289 Mass Termination	1.06 kg (2 lb 5.5 oz)
NI USB-6281 OEM	261 g (9.2 oz)
NI USB-6289 OEM	274 g (9.6 oz)
NI USB-6281 Screw Terminal	1.46 kg (3 lb 3.4 oz)
NI USB-6289 Screw Terminal	1.52 kg (3 lb 5.5 oz)
I/O connector	
NI PCI/PXI-6280/6281	1 68-pin VHDCI
NI PCI/PXI-6284/6289	2 68-pin VHDCI
NI USB-6281 Mass Termination	1 68-pin SCSI
NI USB-6289 Mass Termination	2 68-pin SCSI
NI USB-6281 OEM	1 34-pin IDC, 1 50-pin IDC
NI USB-6289 OEM	2 34-pin IDC, 2 50-pin IDC
NI USB-6281 Screw Terminal	64 screw terminals
NI USB-6289 Screw Terminal	128 screw terminals
USB-6281/6289 Screw Terminal wiring	16-28 AWG

Maximum Working Voltage[12]

NI 6280/6281/6284/6289 channel-to-earth	11 V, Measurement Category I

Caution Do *not* use for measurements within Categories II, III, or IV.

[12] *Maximum working voltage* refers to the signal voltage plus the common-mode voltage.

Environmental

Operating temperature	
PCI/PXI devices	0 to 55 °C
USB devices	0 to 45 °C
Storage temperature	-20 to 70 °C
Humidity	10 to 90% RH, noncondensing
Maximum altitude	2,000 m
Pollution Degree (indoor use only)	2

Shock and Vibration (PXI Devices Only)

Operational shock	30 g peak, half-sine, 11 ms pulse (Tested in accordance with IEC-60068-2-27. Test profile developed in accordance with MIL-PRF-28800F.)
Random vibration	
Operating	5 to 500 Hz, 0.3 g_{rms}

Nonoperating	5 to 500 Hz, 2.4 g_{rms} (Tested in accordance with IEC-60068-2-64. Nonoperating test profile exceeds the requirements of MIL-PRF-28800F, Class 3.)

Safety

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326 (IEC 61326): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For the standards applied to assess the EMC of this product, refer to the Online Product Certification section.

Note For EMC compliance, operate this product according to the documentation.

Note For EMC compliance, operate this device with shielded cables.

CE Compliance

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit ni.com/certification, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial not only to the environment but also to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of their life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers and National Instruments WEEE initiatives, visit ni.com/environment/weee.htm.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

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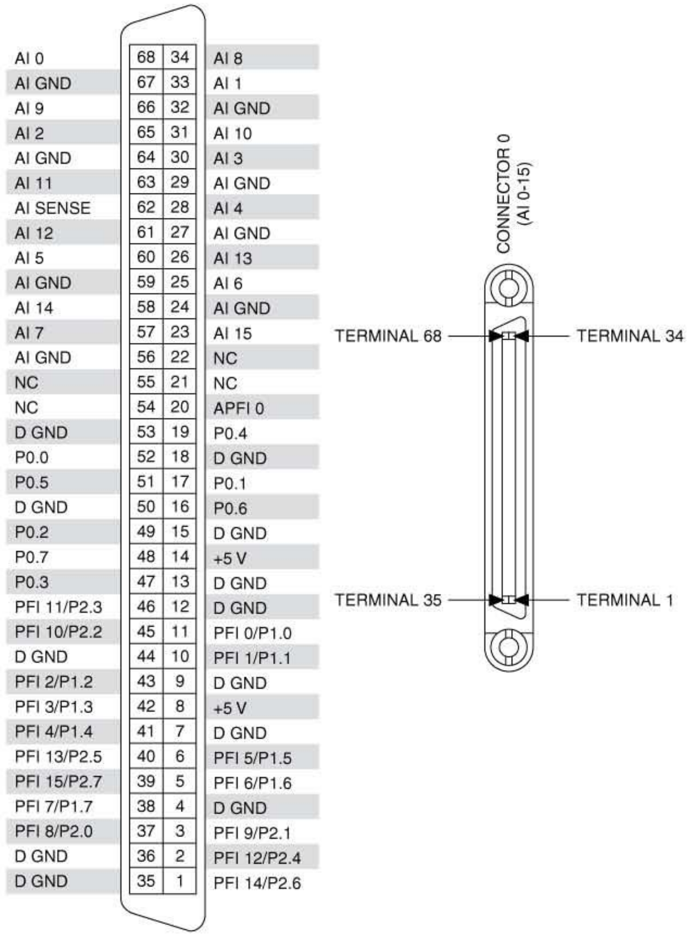
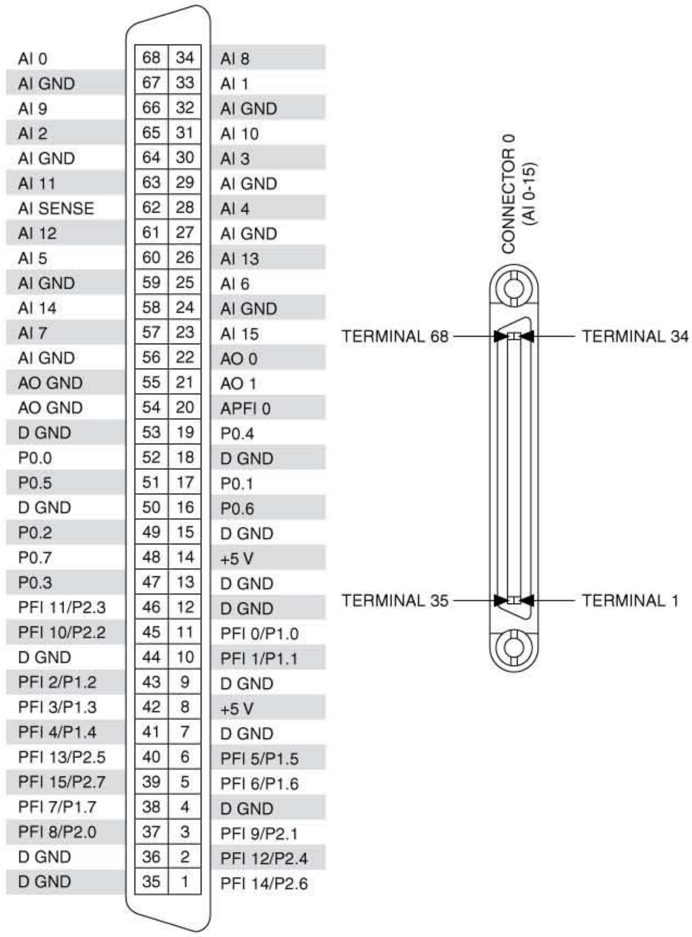
Pinouts/Front Panel Connections



NC = No Connect

NI PCI/PXI-6280 Pinout



NI PCI/PXI-6281 Pinout

18/20

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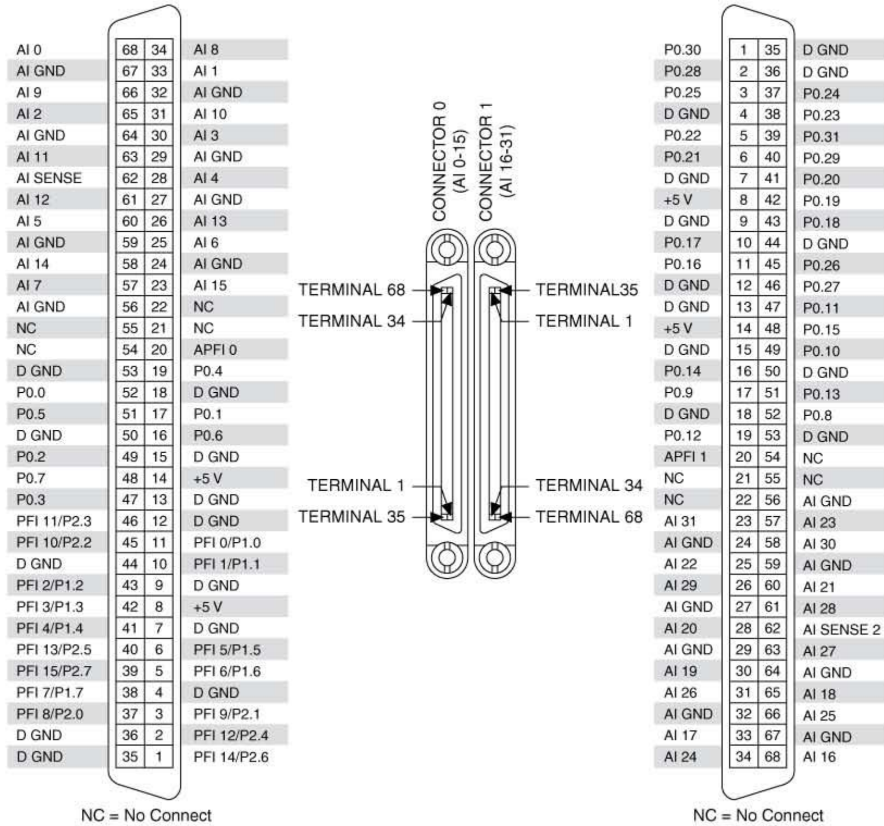
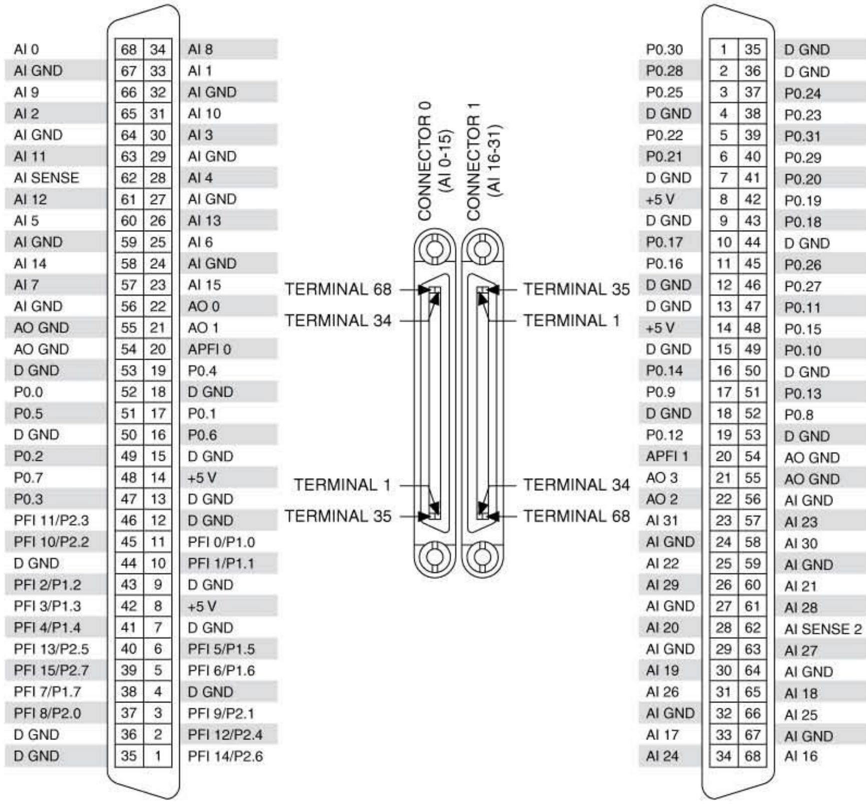


NI PCI/PXI-6284 Pinout

19/20 www.ni.com



NI PCI/PXI-6289 Pinout

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APPENDIX C. PACIFIC INSTRUMENTS MODEL 6100/6160

PACIFIC INSTRUMENTS

MODEL 6100/6160
PROGRAMMABLE TRANSDUCER AMPLIFIERS

FEATURES

- Voltage & current excitation with remote sensing
- Isolated excitation and input
- 300 Volts common mode
- Automatic zero and balance
- Resistive or DAC shunt calibration
- Gains 1 to 5,000
- 50 kHz Bandwidth, 100 kHz optional
- Six-pole, low-pass filter
- Dual analog outputs
- Program monitoring of output and excitation

INPUT ISOLATED TRANSDUCER SIGNAL CONDITIONING

Series 6100 is an automated, transducer signal conditioning amplifier system. The basic mainframe holds 32 channels, which is expandable to 1,024 channels. It is available with RS-232, IEEE-488, USB or Ethernet interface and software for Windows 2000 and XP.

The 6160 is a two-channel transducer amplifier-filter module. Each channel has isolated input and excitation, 50 kHz bandwidth and two outputs that can be filtered or wideband. Bandwidth of 100 kHz is optional.

The bridge input is ten-wire shielded; input (2), excitation (2), sense (2) and shunt calibration (4) with programmable constant voltage or constant current excitation. Programmable bridge completion eliminates plug-in jumpers, loose resistors and component soldering. Automatic bridge balancing ahead of the instrumentation amplifier accommodates large unbalances without limiting gain or dynamic range.

The input and excitation are isolated from the outputs, power and control interface. This gives the user complete freedom to ground the input transducer without creating ground loops that introduce noise and offset errors. The isolation provides for operation with up to ±300 Volts of common mode applied to the input.

The differential instrumentation amplifier has programmable gains from 1 to 5,000 and automatic zero. The standard filter is a six-pole Bessel with four programmable bandwidths and wideband. An optional four-pole Bessel filter has continuously programmable bandwidth with 1 Hz resolution below 1 kHz and 5 Hz above 1 kHz. Each channel has two buffered, ±10 Volt outputs. The output and excitation can be digitally monitored using any of the supported interfaces.

A "features card" provides shunt calibration using dedicated inputs. The standard is two-step, resistive shunt calibration that may be applied by program selection to internal or external bridge arms. Four-step resistive shunt calibration and shunt calibration using a DAC with 16-bit resolution are also available. Voltage substitution employing an external, traceable standard is provided for gain calibration. Automatic zero and gain calibration are implemented in PI610 software.

The mainframe interfaces are IEEE-488, RS-232, Ethernet and USB 2.0. The basic 6100 has both the IEEE-488 and RS-232 interfaces. The the 6000U has a USB 2.0 interface. Ethernet interface is provided using an adapter. Previous programmed operating parameters and the balance and calibration settings are automatically loaded during power-up and by Reset.

User programming is facilitated by a high-level instruction set that is present in the mainframe or USB driver. The 6160 is programmed by text strings sent from the user's application. Optional Windows application software, PI610, is fully configured and ready to use. It provides menu programming of operating parameters or can download parameters from an Access compatible database file. It includes a window that graphically displays amplifier excitation voltage and current and output. PI610 may also be used as a component module DLL with LabView, Visual Basic, Excel or other windows programming language to design custom control and operator interfaces.

Panel60 is maintenance and calibration software for all Series 6000 and 6100 products. It is a beneficial tool that enables the technician to verify amplifier settings and configuration and make adjustments to gain, zero, balance and other calibrated parameters. A calibration system, ACS2000, automatically calibrates amplifier gain and excitation and certifies the amplifier to the published specification with an archived record of measured performance.

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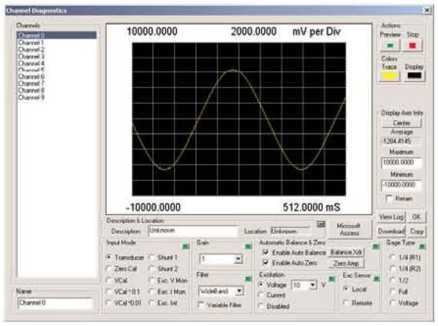
SYSTEM

- Fully programmable, no manual controls
- Thirty-two channels per enclosure, up to 1,024 channels per system
- Programmed operating parameters are automatically loaded at power-up
- Two sets of high and low-level alarms with the capability for controlling external equipment
- Integral tray routes input and output cables to exit from the rear
- Choice of IEEE-488, RS232, USB 2.0 or Ethernet interface for programming and control
- Automatic calibration system, ACS2000, provides fast and automated calibration and certification to traceable standards.

CHANNEL MODULES

- Isolated input and excitation for use with grounded transducers
- Programmable voltage or current excitation with remote sensing
- Programmable bridge completion, no jumpers or rewiring to change gage types
- Versatile 10-wire shielded input handles all gages
- High-resolution gain and excitation programming
- Two or four-step shunt, DAC simulated shunt and voltage substitution calibration
- Automatic balance, zero and calibration make test setup quick and easy
- Test connector on front of module gives access to excitation, sense, inputs and output.



PI610 SOFTWARE

- Ready to run or component module DLL software
- Design a custom GUI using Visual Basic, LabView, Access or Excel
- Use spreadsheet, database or built-in screens to program channel settings
- Copy function makes adding channels quick and easy
- Simplify calibration using automatic procedures.
- Controls external voltage standard for traceable gain calibration
- Real-time graphical display of excitation and output is useful for detecting installation problems

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PACIFIC INSTRUMENTS

CONSTANT VOLTAGE

Voltage ....Programmable from 0.1 to 20 Volts with 0.5 mV resolution. Calibrated 2-Volt steps ±0.1%.

Remote Sense ......Programmable local or remote sense, sense current less than 10 uA.

Current ....50mA limited to 70mA maximum.

Regulation ....±0.01% over input voltage range and no-load to full-load.

Stability ....±0.01% for 30 days. Temperature coefficient less than ±0.005%/°C

Noise ....200 µV peak-to-peak, DC to 10 kHz

Monitor....................Excitation voltage or current is read by a program instruction. Accuracy is ±0.2%.

CONSTANT CURRENT

Output Range ....Programmable 0.1mA to 51.2 mA with 1 µA resolution. Calibrated 5 mA steps ±0.1%.

Compliance ....0.1 to 20 Volts.

Regulation ....±0.01% or ±0.1µA for 10% line change.

Noise ....2 µA or 5 µV peak-to-peak DC to 10 kHz.

Stability ....±0.01% or ±2 µA for 30 days. Temperature coefficient is less than ±0.005% or ±1 µA/°C.

Monitor....................Excitation voltage or current is read by a program instruction. Accuracy is ±0.2%.

INPUT - BRIDGE

Configuration ....2 to 10 wire plus shield; input (2), excitation (2), sense (2) and shunt calibration (4). Programmable bridge completion for half bridges and 120 Ohm and 350 Ohm quarter bridges. Other gage resistances by request.

Bridge Balance ....Automatic by program control. Balance accuracy ±0.05% of range, ±1 mV RTO. Stability ±0.02% for 8 hours, ±0.005%/°C. Range set by resistor up to 25 mV/V, 2.5 mV/V (350 Ohms) installed.

Impedance ....50 Megohms, shunted by 500 pF.

Protection ....±50 Volts, differential and ±350 Volts common mode.

CALIBRATION

Shunt (Standard) ....Two steps of single shunt. Calibration resistors are installed on terminals. Program selection of internal or external shunt connection.

Shunt Resistors........Installed shunt resistors provide 0.502 and 0.250, ±1% mV/V for 350 Ohm bridge. Customer specified, 0.01% shunt resistors are available.

Voltage ....Alternate input for external calibration source. Programmable 1, 0.1 and 0.01, attenuation with ±0.02% accuracy. Attenuator output may be connected to bus for external monitoring.

Zero Calibration ......Amplifier input disconnected and shorted for zero calibration.

CALIBRATION OPTIONS

Shunt (S4) ....Four-steps of single shunt. Calibration resistors installed on terminals. May be wired for local shunt at the input connector.

Sim Shunt (DAC) ....A programmable DAC referenced to the excitation voltage applies simulated shunt. Two precision range resistors program selected. Resolution is 0.0015% (16-bits)

AMPLIFIER

Range......................±2 mV to ±10 Volts full scale.

Gain ....Programmable from 1 to 5,000 with 0.05% resolution.

Gain Steps ....Sixteen calibrated gain steps are provided: 1, 2, 3, 5, 10, 20, 30, 50, 100, 200, 300, 500, 1,000, 2,000, 3,000 and 5,000 with ±0.05% accuracy.

Gain Stability ....±0.02% for 30 days, ±0.005%/°C.

Linearity ....±0.01% for gains < 1000, ±0.02% for gain 1000 and higher.

Common Mode ......60 dB plus gain in dB to 120 dB for balanced input and 110 dB for a 350 Ohm source unbalance, DC to 60 Hz.

CM Voltage ....±300 Volts operating.

Zero ....Automatic zero to ±2 µV RTI or ±1.0 mV RTO whichever is greater.

Zero Stability ....±5 µV RTI, ±1mV RTO at constant temperature, ±1 µV RTI, ±0.2 mV RTO/°C.

Source Current ....±25 nA, ±0.05 nA/°C.

Noise (10 kHz)........2.0 µV RTI plus 0.3 mV RTO, RMS.

Bandwidth ....50 kHz (-3 dB) for gains 1 to 1,000, 20kHz (-3 dB) for gains above 1,000.

Bandwidth (HF) ......100 kHz (-3 dB) for gains 1 to 1,000, 50 kHz (-3 dB) for gains above 1,000.

Slew Rate................5 V/uS.

Overload Recovery....120 µS to within ±0.1% for a 10 times overload to ±10 Volts.

Monitor....................Output is read by a program instruction. Resolution is ±0.003%.

Output ....Two ±10 Volt full scale buffered outputs. Each may be program selected for filtered or wideband response.

FILTER (STANDARD)

Type ....Six-pole, low-pass Bessel (36 dB/octave).

Frequency................Four programmable filter bandwidths, 150 Hz, 625 Hz, 2.5 kHz, 10 kHz and wideband.

Frequency (HF) ....Four programmable filter bandwidths, 300 Hz, 1.25 kHz, 5 kHz, 20 kHz and wideband.

FILTER (OPTIONS)

Type ....Four-pole, low-pass Bessel (24 dB/octave)

Freq. (PFBE2) ....4 Hz to 1 kHz, 1 Hz resolution, 1 kHz to 10 kHz, 5 Hz resolution, ±2% accuracy.

Freq. (PHFBE2) ......10 Hz to 1 kHz, 1 Hz resolution, 1 kHz to 20 kHz, 5 Hz resolution, ±2% accuracy.

INTERFACE CONNECTORS

All connectors for input and output of analog and control signals are mounted on the front edge of the 6160 module. All mating connectors, except BNC type, are furnished.

Transducer ....Each channel has a 15-pin Type D input connector

Output ....Both outputs for both channels in a 9-pin Type D connector.

Test ....15-Pin Type D connector provides access to excitation, sense, inputs and output. Uses the 6087 Test Fixture to access signals in the connector.

ENCLOSURES AND INTERFACE

The rack enclosures provide slots for 16 modules, 32 channels using the 6160. They contain a channel controller and power supply that operates on 115 or 230 VAC. The basic 6100 Mainframe enclosure includes IEEE-488 and RS232 interfaces. One 6100 mainframe will control up to thirty-one 6001 slave enclosures. Ethernet is provided by an adapter on the 6100. The 6100U has a USB 2.0 interface. USB hubs are used to support multiple 6100U enclosures.

INDICATORS

Pwr/Adr....................Indicates power is applied to the enclosure. Blinks when a channel in the enclosure is being addressed by a program instruction.

Reset ....Indicates that enclosure reset is being asserted.

Calibration ....Indicates that one or more channels are in a calibration mode.

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PACIFIC INSTRUMENTS

PROGRAM INSTRUCTIONS

The following program instructions are provided to implement system programming and operation.

Address	Selects single channel or group of channels for subsequent programming.
Reset	Stops any operation in process, sets all programmable parameters to the stored settings.
Gain	Program gain of channel, followed by autozero.
Filter	Program filter steps and wideband for a channel, followed by autozero.
Auto-Balance	Initiate automatic balance, preceded by autozero.
Cal Enable	Enables or disables selected calibration mode.
Calibration	Selects calibration mode and step.
Excitation	Select voltage or current excitation, set voltage or current level and select remote or local sensing.
Verification	Read back channel status and parameters.
Read Excitation	Returns value of excitation voltage or current.
Read Output	Return value of channel output.

PHYSICAL

MODULE

Size	0.8 inch wide by 9 inches high by 9 inches deep.
Weight	Approximately 13 oz.
Mounting	The module slides into the enclosure on card guides accessed through the front door and is secured by locking extractors. Rear access is not required to change modules or input and output connectors.

RACK ENCLOSURE (Master & Slave)

Module Slots	16.
Cable Tray	A built-in tray routes input and output cables to exit from the rear of the enclosure.
Cooling	Built-in fan with replaceable filter.
Size	19 inches wide by 14 inches tall by 23 inches deep (including mating connectors).
Weight	Approximately 60 pounds, with all modules installed.
Power	115 or 230 VAC ±10%, 47 to 63 Hz.

ENVIRONMENTAL

Temperature	Operating, 0°C to +50°C.
Humidity	95% without condensation.
Shock/Vibration	Normal shipping and handling of laboratory instruments.

CALIBRATION SYSTEM

Pacific Instruments Model ACS2000, Automated Calibration System will align, calibrate and certify Series 6000 analog input modules to factory or user performance specifications. A fully automated, PC controlled test station it has the flexibility to run a single performance test or complete calibration and certification procedures. Measured performance data is archived by unit serial number. A print utility generates hard copy test reports.

ORDERING INFORMATION

MODULE

6160	Two-channel transducer amplifier, 50 kHz bandwidth, 100 kS/s.
6160HF	Two-channel transducer amplifier, 100 kHz bandwidth, 200 kS/s.

OPTIONS

6000-PFBE2	Continuously programmable filter, 4 Hz to 10 kHz.
6000-PHFBE2	Continuously programmable filter, 10 Hz to 20 kHz.
6060-DAC	DAC controlled simulated shunt.
6060-S4	Four-step shunt calibration.

ENCLOSURES

6100	Mainframe enclosure, 16 slot with IEEE-488 and RS232 interfaces.
6100U	Mainframe enclosure, 16-slot with USB 2.0 programming and control interface.
6101	Slave enclosure, 16-slot. Used with 6000 mainframes.

ENCLOSURE OPTIONS

6000-CP	Remote connector panel with 15-pin, ¼ turn twist lock MIL type input connectors and BNC output connectors. Mating input connectors are furnished. Cable length is 2 meters.
6000-E	Ethernet adapter for 6100 Mainframe.
6087-6060	Test fixture with 1 meter cable.

SOFTWARE

PI610	Operating software for Windows 2000/XP. Supplied as a turnkey application and DLL.
PANEL60	Maintenance and calibration software for Windows 2000/XP.

CALIBRATION SYSTEM

ACS2000	Calibration & certification system with fixture for Model 6060.

6087-6060 Test Fixture

Attached to the test connector on the 6060 module it provides test points for: Transducer input, amplifier input, shunt calibration, excitation output, excitation sense and amplifier output

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APPENDIX D. PACIFIC INSTRUMENTS MODEL 6100/6165

MODEL 6100/6165
PROGRAMMABLE INSTRUMENTATION AMPLIFIERS

FEATURES

- Isolated input
- 300 Volts common mode
- Automatic zero
- Gains 1 to 5,000
- Voltage Substitution Calibration
- 50 kHz Bandwidth, 100 kHz optional
- Six-pole, low-pass filter
- Dual analog outputs
- Program monitoring of output

INPUT-ISOLATED INSTRUMENTATION AMPLIFIER

Series 6100 is an automated, transducer signal conditioning amplifier system. The basic mainframe holds 32 channels, which is expandable to 1,024 channels. It is available with RS-232, IEEE-488, USB or Ethernet interface and software for Windows 2000 and XP.

The 6165 is a two-channel amplifier-filter module. Each channel has isolated input, 50 kHz bandwidth and two outputs that can be filtered or wideband. Bandwidth of 100 kHz is optional.

The input is two-wire shielded and is isolated from the outputs, power and control interface. This gives the user complete freedom to ground the input without creating ground loops that introduce noise and offset errors. The isolation provides for operation with up to ±300 Volts of common mode applied to the input.

The differential instrumentation amplifier has programmable gains from 1 to 5,000 and automatic zero. The standard filter is a six-pole Bessel with four programmable bandwidths and wideband. An optional four-pole Bessel filter has continuously programmable bandwidth with 1 Hz resolution below 1 kHz and 5 Hz above 1 kHz. Each channel has two buffered, ±10 Volt outputs. The output can be digitally monitored using any of the supported interfaces.

Voltage substitution calibration, employing an external standard, is provided for gain calibration. Automatic zero and gain calibration are implemented in PI610 software.

The mainframe interfaces are IEEE-488, RS-232, Ethernet and USB 2.0. The 6100 has both the IEEE-488 and RS-232 interfaces. The the 6000U has a USB 2.0 interface. Ethernet interface can be provided using an adapter. Previous programmed operating parameters and the calibration settings are automatically loaded during power-up and by Reset.

User programming is facilitated by a high-level instruction set that is present in the mainframe or USB driver. The 6160 is programmed by text strings sent from the user's application. Optional Windows application software, PI610, is fully configured and ready to use. It provides menu programming of operating parameters or can download parameters from an Access compatible database file. It includes a window that graphically displays the amplifier output. PI610 may also be used as a component module DLL with LabView, Visual Basic, Excel or other windows programming language to design custom control and operator interfaces.

Panel60 is maintenance and calibration software for all Series 6000 and 6100 products. It is a beneficial tool that enables the technician to verify amplifier settings and configuration and make adjustments to gain, zero and other calibrated parameters. A calibration system, ACS2000, automatically calibrates amplifier gain and certifies the amplifier to the published specification with an archived record of measured performance.

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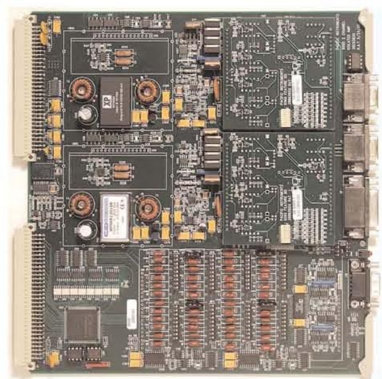
PACIFIC INSTRUMENTS

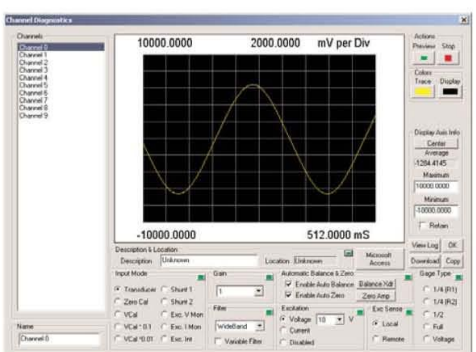
SYSTEM

- Fully programmable, no manual controls
- Thirty-two channels per enclosure, up to 1,024 channels per system
- Programmed operating parameters are automatically loaded at power-up
- Integral tray routes input and output cables to exit from the rear
- Choice of IEEE-488, RS232, USB 2.0 or Ethernet interface for programming and control
- Automatic calibration system, ACS2000, provides fast and automated calibration and certification to traceable standards.

CHANNEL MODULES

- Two channels per module
- Isolated input for use with grounded sources
- 300 Volt operating common mode
- High-resolution gain programming
- Highest accuracy, <0.05% for gain 1,000
- Voltage substitution calibration
- Automatic zero and calibration make test setup quick and easy
- Six-pole anti-alias filter
- Dual buffered outputs, digital output monitor
- Two sets of high and low-level alarms





PI610 SOFTWARE

- Ready to run or Application Programmers software
- Design a custom GUI using Visual Basic, LabView, Access or Excel
- Use spreadsheet, database or built-in screens to program channel settings
- Copy function makes adding channels quick and easy
- Simplify calibration using automatic procedures.
- Controls external voltage standard for traceable gain calibration
- Real-time monitor graphically displays amplifier output

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PACIFIC INSTRUMENTS

INPUT

Configuration ....2 wire plus shield
Impedance ....50 Megohms, shunted by 500 pF.
Protection ....±50 Volts, differential and ±350 Volts common mode.

CALIBRATION

Voltage ....Alternate input for external calibration source. Programmable 1, 0.1 and 0.01, attenuation with ±0.02% accuracy. Attenuator output may be connected to bus for external monitoring.
Zero Calibration ......Amplifier input disconnected and shorted for zero calibration.

AMPLIFIER

Range......................±2 mV to ±10 Volts full scale.
Gain ....Programmable from 1 to 5,000 with 0.05% resolution.
Gain Steps ....Sixteen calibrated gain steps are provided: 1, 2, 3, 5, 10, 20, 30, 50, 100, 200, 300, 500, 1,000, 2,000, 3,000 and 5,000 with ±0.05% accuracy.
Gain Stability ....±0.02% for 30 days, ±0.005%/°C.
Linearity ....±0.01% for gains < 1000,.±0.02% for gain 1000 and higher.
Common Mode ......60 dB plus gain in dB to 120 dB for balanced input and 110 dB for a 350 Ohm source unbalance, DC to 60 Hz.
CM Voltage ....±300 Volts operating.
Zero ....Automatic zero to ±2 µV RTI or ±1.0 mV RTO whichever is greater.
Zero Stability ....±5 µV RTI, ±1mV RTO at constant temperature, ±1 µV RTI, ±0.2 mV RTO/°C.
Source Current ....±25 nA, ±0.05 nA/°C.
Noise (10 kHz)........2.0 µV RTI plus 0.3 mV RTO, RMS.
Bandwidth ....50 kHz (-3 dB) for gains 1 to 1,000, 20kHz (-3 dB) for gains above 1,000.
Bandwidth (HF) ......100 kHz (-3 dB) for gains 1 to 1,000, 50 kHz (-3 dB) for gains above 1,000.
Slew Rate................5 V/uS.
Overload Recovery....120 µS to within ±0.1% for a 10 times overload to ±10 Volts.
Monitor....................Output is read by a program instruction. Resolution is ±0.003%.
Output ....Two ±10 Volt full scale buffered outputs. Each may be program selected for filtered or wideband response.

FILTER (STANDARD)

Type ....Six-pole, low-pass Bessel (36 dB/octave).
Frequency................Four programmable filter bandwidths, 150 Hz, 625 Hz, 2.5 kHz, 10 kHz and wideband.
Frequency (HF) ....Four programmable filter bandwidths, 300 Hz, 1.25 kHz, 5 kHz, 20 kHz and wideband.

FILTER (OPTIONS)

Type ....Four-pole, low-pass Bessel (24 dB/octave)
Freq. (PFBE2) ....4 Hz to 1 kHz, 1 Hz resolution, 1 kHz to 10 kHz, 5 Hz resolution, ±2% accuracy.
Freq. (PHFBE2) ......10 Hz to 1 kHz, 1 Hz resolution, 1 kHz to 20 kHz, 5 Hz resolution, ±2% accuracy.

INTERFACE CONNECTORS

All connectors for input and output of analog and control signals are mounted on the front edge of the 6165 module. All mating connectors, except BNC type, are furnished.

Input ....Each channel has a 15-pin Type D input connector
Output ....Both outputs for both channels in a 9-pin Type D connector.

ENCLOSURES AND INTERFACE

The rack enclosures provide slots for 16 modules, 32 channels using the 6165. They contain a channel controller and power supply that operates on 115 or 230 VAC. The basic 6100 Mainframe enclosure includes IEEE-488 and RS232 interfaces. One 6100 mainframe will control up to thirty-one 6001 slave enclosures. Ethernet is provided by an adapter on the 6100. The 6100U has a USB 2.0 interface. USB hubs are used to support multiple 6100U enclosures.

INDICATORS

Pwr/Adr....................Indicates power is applied to the enclosure. Blinks when a channel in the enclosure is being addressed by a program instruction.
Reset ....Indicates that enclosure reset is being asserted.
Calibration ....Indicates that one or more channels are in a calibration mode.

PROGRAM INSTRUCTIONS

The following program instructions are provided to implement system programming and operation.

Address ....Selects single channel or group of channels for subsequent programming.
Reset ....Stops any operation in process, sets all programmable parameters to the stored settings.
Gain......................Program gain of channel, followed by autozero.
Filter ....Program filter steps and wideband for a channel, followed by autozero.
Auto-Zero ....Nulls the outputs with the input disconnected and shorted.
Cal Enable ....Enables or disables selected calibration mode.
Calibration ....Selects calibration mode and step.
Verification ....Read back channel status and parameters.
Read Output ....Return value of channel output.

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PHYSICAL

MODULE

Size ....0.8 inch wide by 9 inches high by 9 inches deep.
Weight ....Approximately 13 oz.
Mounting ....The module slides into the enclosure on card guides accessed through the front door and is secured by locking extractors. Rear access is not required to change modules or input and output connectors.

RACK ENCLOSURE (Master & Slave)

Module Slots ....16.
Cable Tray ....A built-in tray routes input and output cables to exit from the rear of the enclosure.
Cooling..................Built-in fan with replaceable filter.
Size ....19 inches wide by 14 inches tall by 23 inches deep (including mating connectors).
Weight ....Approximately 60 pounds, with all modules installed.
Power....................115 or 230 VAC ±10%, 47 to 63 Hz.

ENVIRONMENTAL

Temperature ....Operating, 0°C to +50°C.
Humidity ....95% without condensation.
Shock/Vibration......Normal shipping and handling of laboratory instruments.

CALIBRATION SYSTEM

Pacific Instruments Model ACS2000, Automated Calibration System will align, calibrate and certify Series 6100 analog input modules to factory or user performance specifications. A fully automated, PC controlled test station, it has the flexibility to run a single performance test or complete calibration and certification procedures. Measured performance data is archived by unit serial number. A print utility generates hard copy test reports.

ORDERING INFORMATION

MODULE

6165 ....Two-channel instrumentation amplifier, 50 kHz bandwidth, 100 kS/s.
6165HF................Two-channel instrumentation amplifier, 100 kHz bandwidth, 200 kS/s.

OPTIONS

6000-PFBE2 ....Continuously programmable filter, 4 Hz to 10 kHz.
6000-PHFBE2 ......Continuously programmable filter, 10 Hz to 20 kHz.

ENCLOSURES

6100 ....Mainframe enclosure, 16-slot with IEEE-488 and RS232 interfaces.
6100U..................Mainframe enclosure, 16-slot with USB 2.0 programming and control interface.
6101 ....Slave enclosure, 16-slot. Used with 6000 mainframes.

ENCLOSURE OPTIONS

6000-E ....Ethernet adapter for 6100 Mainframe.

SOFTWARE

PI610 ....Operating software for Windows 2000/XP. Supplied as a turnkey application and DLL.
PANEL60 ....Maintenance and calibration software for Windows 2000/XP.

CALIBRATION SYSTEM

ACS2000 ....Calibration & certification system with fixture for Model 6165.

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NOMENCLATURE

ADC	Analog-to-digital converter
dB	Decibels
FS	Full scale
G	Gain
mV	Millivolts
nA	Nano amperes
NI	National Instruments
NIST	National Institute of Standards and Technology
psia	Pounds square inch absolute
rms	Root mean square
rss	Root sum square
RTI	Relative to input
RTO	Relative to output
U_{95}	95% interval for measurement uncertainty
V	Volts
σ	Standard deviation
Δ	Delta or difference
μV	Microvolts